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The impact of high yielding varieties of rice on a settlement scheme in Sri Lanka*

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INTRODUCTION

REMARKABLE success in introducing a set of improved elements of productive technology has been achieved following the discovery of the highyielding varieties of foodgrains, and their commercial application. The rapid spread of the new practices in certain areas could be attributed largely to the technological breakthrough which has resulted in a jump in productivity, and opened the way for making a fortune out of farming, and turning many of the hitherto non-viable farms into viable ones. The new varieties of traditional foodgrains in particular have touched off a transformation in the growing of crops, and this development could be considered to be the basic factor underlying the so called " green revolution ". The " green revolution " has attracted the universal interest of all those concerned, and helped to dispel the conventional wisdom with regard to change and development among farmers of the third world. Strategies involving high yielding varieties of seeds for agricultural development have been adopted or are under active consideration by governments the world over. This paper examines the concerted efforts by the Government of Sri Lanka towards adopting such a strategy in order to bring about rapid changes in the levels of productivity in the island in general and on settlement schemes in particular. Settlement Schemes † have been in existence for over four decades and have had a special significance in the history of alienation and development of crown land in Ceylon.[1] At present there are 80 major colonisation schemes

* This paper is extracted from a larger study a "Report on the Economic and Social Implications of the Introduction of High-Yielding Varieties of Rice on Settlement Schemes in Ceylon : A Case Study " written by the author. This study was sponsored by the United Nations Research Institute for Social Development, Geneva, in connection with the UNDP Glo 2 Survey conducted in Ceylon in 1971/72. Grateful thanks are acknowledged to the UNRISD for their kind assistance.

† The terms Colonisation Schemes and Settlement Schemes are used synonymouslys and refer to government sponsored settlement on crown land in an area away from settler, traditional villages.

covering an area of 304,355 acres of irrigable and unirrigable land [2]. The average size of holding of paddy (rice) land is 3 acres while that of unirrigable highland is 1.8 acres.[7] Colonisation schemes have been under constant criticism due to their poor levels of performance. Following the recommendations of the I.B.R.D. in 1966 [8], which was particularly critical of the colonisation schemes, a number of remedial measures were suggested. These recommendations which included methods for increasing productivity and economies in the use of irrigation water were tested on a pilot basis in one major colonisation scheme. Encouraged by the success of the pilot project, nine other colonisation schemes were designated "special Projects"* in the following year. At present there are fifteen such projects. The objectives of the "Special Projects" were fundamentally to increase the yield of paddy which is the mainstay of the farming system, encourage the cultivation of other field crops, promote the adoption of improved farm practices and the development of farmer organizations [9].

In this study an attempt is made to examine the impact of the agricultural intensification programme on a selected "special project". In this programme the high-yielding varieties of rice (HYV) formed a vital facet. The economic and social consequences of the improved type of farming using (HYV) would be identified and estimated on the basis of a comparison of the organization of production and the livelihood of the different socio-economic sectors, prior to and after the initiation of the project.

METHODOLOGY

Any claim to identify changes affecting the production and livelihood of the rural population must be based on situations anterior to the initiation of programmes introducing HYV. Further, cognizance of the immanent socio-economic processes which had brought about changes in the locality even in the absence of a major government effort to induct technical advance should be taken into consideration if we are to realistically appraise the impact of HYV. The methodological approach clearly has to be positive and not normative as we are attempting to examine situations anterior and posterior to the introduction of HYV. The problem of data would be paramount in such an investigation. A production function approach would be limited by the lack of suitable time series data relevant to such an analysis.

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* This concept is analogous to the Intensive Agricultural Development Programme in India which was on a district basis.

Moreover, the period involved is too short to permit the consideration of many variables. Further, the analysis being confined to a few variables defined independently would not permit a study in depth of the shifts in the condition and the conduct of rural people under the influence of the alteration of their economies and technological systems. This could only be achieved through a close scrutiny of the many dimensions of community life within the matrix of which conditions change and decisions are made. Therefore, the method of investigation had to be shifted to the conventional farm management survey approach of interviewing a sample of farmers. To obtain an insight into the impact of HYV on other members of the community a similar approach based on personal interviews was resorted to.

The choice of a "Special Project" for the study was largely determined by two factors, viz., representativeness and the availability of antecendent data. On this basis the Minipe Colonisation Scheme was selected. A random sample of 55 farmers and also seven non-farmers who resided in the community and derived their livelihoods from the farming community were selected for study.

The relevant antecedent information was obtained from official records, interviews with old residents of the locality and the farmers in the sample chosen for study. Another very valuable source of antecedent data was the benchmark survey conducted in the locality prior to the establishment of a "Special Project" in 1967[5]. Detailed questionnaires eliciting informaton on land holdings, tenure, production technology, expenditure, production, income, labour utilization, marketing, motivations and attitudes, diffusion and adoption of modern technological elements, credit and so on, were administered to the farmers in the sample. The information covered the period 1966/67 to 1970/71.

Great reliance was placed on the ability of farmers to recall the relevant information. However, this would not vitiate the credibility of the data as it concerned paddy cultivation which is the main source of livelihood of the farmers and it would be reasonable to assume that farmers would have a vivid recollection of the operations involved. Every effort was made to minimise sampling and non-sampling errors of the investigation. In this regard the familiarity of the locality enabled any inaccuracies to be easily detected and rectified.

FACTORS OF CHANGE

Some changes in the levels of production and livelihood of the community had taken place since the inception of the colony in 1941. Some of the more important variables which may have influenced the lives and the livelihoods of the farmers in the colony are, the declining land-man ratios, increasing capital-land ratios, improvements in general communications and the development of farmer organisations such as the co-operatives and cultivation committees. Another important influence was the extension service which existed in the colony from its inception. The milieu of socio-economic and political factors which had existed had not brought about any substantial development of the colony. It was reported in the socio-economic survey conducted in 1967/68 [5] that the level of production was 37 bushels per acre which was below the national average at that time.

The main reorganisation effected in the colonisation schemes designated as " Special Projects " were the intensification of the extension services and the appointment of a resident project manager whose duties were to co-ordinate the activities of the various government departments to ensure a better supply of the required inputs in time and form. A greater effort was made to encourage farmers to innovate. Awareness of the modern farm technology was achieved by demonstrations on farmers fields, distribution of mini-kits* to farmers, and greater inter-personal communications between farmers and extension agents.

IMPACT OF PRODUCTION

The central feature of the economic change which may be anticipated by the successful introduction of HYV is a jump in productivity. But this could only be achieved and given permanence by radical changes in the organisation of the farm both in terms of resource use and husbandry practices. In this section an attempt is made to examine the changes, if any, which have taken place in the technological elements of production, cultivation techniques, farm reorganization and the levels of production as a consequence of the introduction of HYV of rice.

(*a*) *Changes in the Technological Elements and Cultivation Techniques:* The intensification of the extension activity and the methods referred to in creating awareness amongst farmers have

* Mini-kits are small bags containing a few HYV of rice with the required complementary nputs. This enabled farmers to grow, observe and select varieties of their own liking.

indeed had salutary effects. All the farmers in the sample reported having tried out the new HYV, as indicated in table A1 and that the initial resistance shown by farmers towards adopting the new varieties has been circumvented. For instance, while an intermediate HYV, H4 took four years before peak adoption was reported, the new HYV have exhibited a much shorter time lag. This behaviour of farmers could be attributed to the confidence placed in the new varieties based on past experiences and also to the confidence reposed in the recommendations of the extension personnel. More than 80 per cent of the area under paddy is now cultivated with HYV. (1, p. 71). A striking feature about the adoption of the new varieties is the large number cultivated. It is commonplace to find farmers growing more than one variety on their fields. This has been observed as a method adopted by farmers to hedge against the risk of adopting HYV. This divisibility of risk is indeed a very effective way of spreading farmers risk and screening the virtues of the different varieties. Another noteworthy feature was the small extents of traditional varieties which were continued to be grown despite a high level of adoption of HYV. This was to produce rice for domestic consumption since the coarse nature of most of the new varieties make them less desirable. Some farmers had given up the use of certain HYV due to problems of pests and disease (IR—8), poor threshability (Taichung Native—1), and inferior yield potential (H—4). It would therefore be clear that farmers go through an informal process of continuous assessment of varieties, selecting discriminately for preferred characteristics.

With the increase in adoption of HYV there has also been a concommittant increase in the use of complementary inputs and the adoption of improved cultivation techniques. It will be evident from table A2 that an increasing number of farmers have fertilized their crops at the recommended rates, transplanted, used weedicides and pesticides and other innovations after the introduction of the new varieties. It would be evident that a radical reorganisation of farm resources and husbandry practices have taken place in the post HYV period. In fact 91 per cent. of the farmers reported the need for the reorganisation of production (1, p. 98).

A greater mechanization of farm operations were also observed (see table A3), in particular the ploughing and threshing operations and the usage of sprayers. It may therefore be postulated that there has been a definite shift towards capital intensive technology, following the introduction of HYV.

(*b*) *Labour Utilization:* The adoption of HYN of rice has not only been capital intensive but also labour intensive. The labour requirements between the ante and post-HYV periods have changed from 51.34 to 68.44 man days (see table A4), which indicates a 31.3 per cent. increase in labour use. A new feature of the post-HYV period has been the trimodal pattern in labour requirements vis-a-vis bi-modal pattern observed in the pre-HYV period. In the pre-HYV period the peak labour demands were for preparatory tillage (42 per cent and harvesting (44 per cent), while presently they account for 29 and 39 per cent respectively. A new dimension which has been introduced into the labour utilization pattern has been the trans-planting operation which accounts for approximately 17 per cent of the labour required.

A change in the type of labour employed has also been observed. More family and hired labour and less exchange labour are now employed. A more than 100 per cent increase in the use of hired labour and a 40 per cent decrease in the use of exchange labour has been noted between the ante and post-HYV periods. The preference for hired labour vis-a-vis exchange labour may be to ensure greater timeliness of operations and to be more selfreliant. Such a development of attitudes could be largely attributed to the greater commercialization of production consequent to the introduction of HYV.

(*c*) *Levels of Production:* A significant jump in productivity has been observed after the introduction of HYV. The average yield per acre for the Maha season has increased by 59.0 * per cent and the Yala season by 58.8 * per cent during the period 1966/67 to 1970/71. This yield increase may be considered phenomenal as the increase in yield observed over the 25 year period 1941-65 was approximately 52 per cent (1, p. 113). Yields of less than 30 bushels per acre which were common in the pre-HYV period are virtually non existent at the present time (see table A5). Further, more than 45 per cent. of the farmers report yields greater than 70 bushels per acre at the present time which were non existent prior to the introduction of HYV. However the impact of HYV on the levels of production have not been uniform and have exhibited a normal distribution pattern.

Another significiant feature was the land augmenting nature of the "new" technology. Althought, the area sown had declined by 18 per cent due to the fragmentation of holdings, the total production and gross returns per farm have increased by 56.49 and 60.13 per cent respectively, during the proid 1966/67 to 1970/71 (see table A6).

* These values are 91.9% and 84.6% for the Maha and Yala seasons respectively if the yield figures from the socio-economic survey of 1967/68 are used.

IMPACT ON LIVELIHOOD

The social consequences of the introduction of HYV could be examined by making before and after comparisons of the levels of livelihood, the composition of the means of livelihood and livelihood expectations. In this section an attempt will be made to evaluate the changes which have taken place in these three aspects of livelihood.

(a) *Levels of Livelihood:* It may be anticipated that a productivity jump would make the average levels of livelihood rise but the effects on different sectors defined by their form of participation in the productive or distributive process are bound to show discrepancies, with some groups being more advantageously placed. It will be clear from table A7 that the distribution of gross incomes has widened after the introduction of HYV. The scale of incomes range between a lower limit of Rs. 1,001-1,500 and upper limit of Rs. 16,001-16,500. It is evident that in the ante-HYV period the incomes were more clustered and that the upper limit was Rs. 11,501-12,000. The benefits of the new varieties have been inequitably distributed with the gap between the rich and poor farmers growing wider. In the ante-HYV period, 26 per cent of the farmers operated below the poverty line, while in the post-HYV period this number has been reduced to 16 per cent. A significiant feature is the emergence of a 'new elite' amongst the farmers constituting 35 per cent of the population and achieving an income level much higher than the maximum in the ante-HYV period. These farmers have clearly benefited most by the HYV. The Lorenz Curve depicted in Figure 1 also demonstrates the widening inequality of the income levels. Another noteworthy feature is that farmers with the smallest acreages seem to have benefited least from the "green revolution". No conclusive evidence was available as to the intensity of cultivation between the different land holdings. Considering the high cost of production, it is postulated that the economic position of farmers is decisive for the adoption of the modern farm technology and consequently farmers with very small holdings will not be able to derive the maximum benefits of HYV.

In general 96.4 per cent of the farmers reported that they were better off while none reported being worse off, althought 3.64 per cent. reported no change. The net income per farm and per acre for the Maha season in the post-HYV period amounts to Rs. 1,826.34 and

* Defined by an income of Rs. 2,400 per annum.

Rs. 512.93 respectively (see table A8). The corresponding figues were Rs. 1,269.50 and Rs. 116 in 1967/68[5]. Between these two periods the cost of production had increased from Rs. 181.00* to Rs. 482.00. Thus, net income per acre had increased by more than four fold despite the fact that the cost of production had increased appreciably.

The production levels on lands rented were much below those on owner operated farms (see table A9). However, even on these lands the levels of production were significantly better than those reported in the pre-HYV period. Further, the levels of production on lands which were rented on a share cropping basis were less than those on a fixed rental. This clearly indicates the greater disincentive effect of a share cropped tenurial arrangement. Landlords now provide both seed and fertilizer, while only seed was provided in the pre-HYV period. Despite the additional contributions made by landlords in the post-HYV period, their share of the net income has increased more than proportionately to that of the tenants (see table A10). The net incomes to landlords have increased by 94.4 per cent while that of tenants by 80 per cent between the periods under consideration.

Other members of the community such as traders, tractor hire and repair agents, etc., have also benefited by the improved technology. An increase in business turnover was reported by them, particularly during the harvesting and immediate post-harvest periods. Agricultural labourers also reported more work days and higher wages.

(*b*) *Means of Livelihood:* Paddy cultivation forms the main source of livelihood (see table A11) and constitutes approximately 70 per cent of the farm income. The cultivation of all other crops accounts for only 13.7 per cent livestock production for 4.77 per cent and farm income for 12.2 per cent of the average gross income. The means of livelihood shows a slight change under the impact of HYV of rice. In the 1967/68 socio-economic survey[5], paddy accounted for 52.5 per cent of the total gross farm income, livestock production for less than 1 per cent and off-farm income for 19.8 per cent. It would therefore be clear that the contribution of farm production to total gross farm income has increase in the post—HYV period. A decline in the off-farm income component reflects the ability of farms to be self-sustaining under the influence of the new farm technology particularly the HYV of rice.

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* Figure derived from the socio-economic survey of the Minipe Colonisation Scheme 1967/68 (5).

It would be evident from table A12 that the marketable surplus of paddy has increased approximately 76 per cent during the period 1966/67 to 1970/71. This increased commercialization of paddy production brought about by the HYV seems to have had spill over effects on other farming activities. The farmers are now more market oriented and have shown an increasing trend towards the diversification of production.

A change in the acreage under cultivation and the consumption of other cereals were also observed. These crops are almost entirely cultivated for domestic consumption and the declining trend observed clearly reflects a change in consumer preference from coarse grains to rice. It is also likely that farmers now prefer to specialise in the production of rice at the expense of the other cereals due to the enhanced opportunities offered by the HYV.

(c) *Livelihood Expectations:* Livelihood expectations could be affected both by the visible productivity jump and by the increased opportunities brought into view by contact with the ampler ways of life. It will be clear from tables A13 and A14, that, since 1968 there has been an improvement in farm and domestic technology. It may be surmised that the livelihood expectations of farmers have been influenced by the HYV of rice. It will be apparent that the purchases of durable consumer goods such as radios, bicycles, sewing machines etc., have increased in the post—HYV period. This reflects both an improvement in the financial position of farmers as well as their expectations.

The farmers were apparently content with their ways of life and were desirous of improving their lot through farming (1, p. 146) A noteworthy feature was that the majority of farmers sons (65.44%) aspired to take to farming with only 14.5 per cent. indicating their preference for white collar jobs. This may be attributed to the satisfactory levels of living prevailing in the colony at the present time.

CONCLUSIONS

Many changes in the lives and livelihoods of the farmers in the settlement scheme have taken place since the initiation of the agricultural intensification programme in 1968. It would be dubious to attempt an estimation of the contribution made by the different components of the programme. However, it would not be unreasonable to attribute these changes in the main to the HYV of rice, since, the other variables influencing production had exisetd prior to the introduction of the new varieties without influencing production in any tangible way.

A reorganization of production with greater commercialization of both the demand and supply aspects were noted. More capital inputs are used and also some of the traditional husbandry practices have been replaced. The new technology has not only been capital intensive but also labour intensive.

A more than 50 per cent increase in productivity was observed but the benefits were inequitably distributed. Although, the cost of production had increased more than twofold the returns had increased more than proportionately. It is postulated that the economic position of farmers was decisive to derive the maximum benefits of modern technology and that the farmers with the smallest acerages have benefited least. The new technology was also found to be land augmenting in nature.

The landlords have benefited more than tenants as a consequence of the improved technology. Other members of the community deriving their livelihood indirectly from farming have also benefited.

Less reliance on off-farm incomes and a greater specialization in rice production were observed. Improvements in farm and domestic technology and livelihood exceptations in general have also taken place.

We may therefore conclude that HYV of rice have had important economic and social consequences on the community under study. However, the benefits have been inequitably distributed and it is imperative to introduce some policy measures to ensure a better distribution and minimize such disparities in order to avoid the social tensions that could arise as a result of such polarization.

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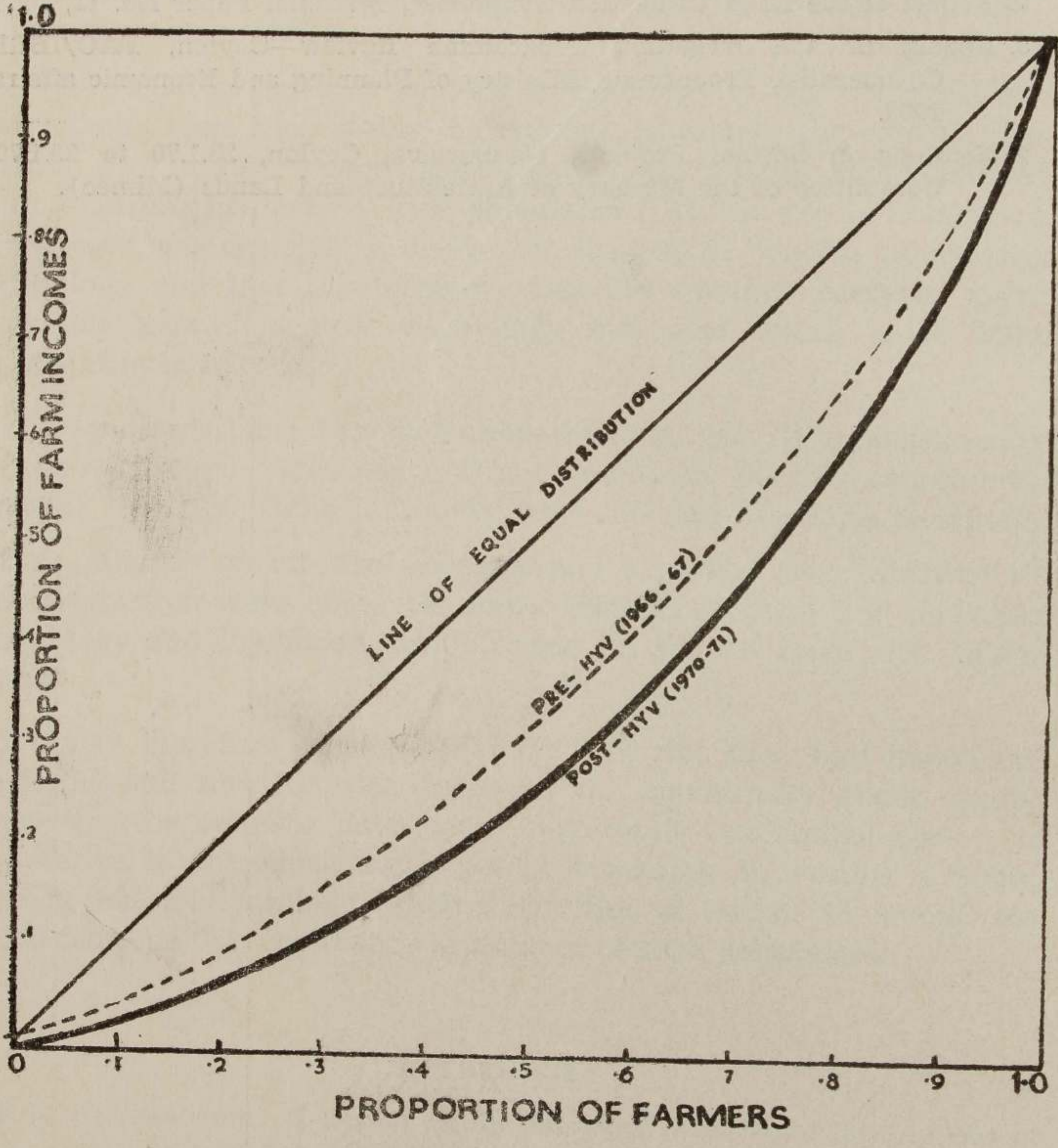

FIG: 1 INCOME DISTRIBUTION OF SETTLEMENT FARMS

TABLE A1—Farmers in Sample Reporting Adoption of HYV of Rice

Variety	Before 1960	Year of Adoption											
		1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Patchaperumal	11	3	—	—	—	—	1	—	—	—	—	—	—
H 4 (1959)	2	11	1	16	1	4	5	5	2	1	1	1	—
H 8 (1962)	—	—	—	—	1	4	2	14	3	2	1	2	—
Taiwan (1966)	—	—	—	—	—	—	—	1	5	2	3	2	1
IR-8 (1968/69)	—	—	—	—	—	—	—	—	—	16	12	13	4
IR-262 (1969)	—	—	—	—	—	—	—	—	—	—	2	3	1
BG-11-11 (1970/71)	—	—	—	—	—	—	—	—	—	—	—	1	32
LD-66 (1970/71)	—	—	—	—	—	—	—	—	—	—	—	—	11
MI-273 (1971)	—	—	—	—	—	—	—	—	—	—	—	—	3

Note.—The years in parentheses represent the year of introduction of the variety.

TABLE A2—The Adoption of Modern Technology in Paddy Cultivation

Innovation	Year of Adoption									
	1955 and before	1956 to 1960	1961 to 1965	1966	1967	1968	1969	1970 and after	Total No. reporting	Level of Adoption Percent.
Tractor Ploughing	22	18	8	1	—	1	2	—	52	94·5
Use of Iron Ploughs for Buffalo ploughing	—	—	—	—	—	2	3	5	11	20·0
Seed disinfection	—	—	—	—	—	1	—	—	1	1·82
Row seeding	—	—	—	—	—	—	1	—	1	1·82
Ordinary Transplanting	—	2	7	6	5	16	5	12	53	96·36
Row Transplanting	—	—	—	1	2	3	1	4	11	20·0
Use of Recommended Fertilizer Rates	1	1	7	2	4	17	8	12	52	94·5
Use of Irrigation Pump	—	—	—	—	2	—	1	2	5	9·09
Row weeders	—	—	—	—	1	1	3	1	3	5·45
Chemical Weed Control	—	—	9	2	2	7	8	7	30	54·55
Use of Insecticides and Fungicides	—	2	10	4	6	16	5	5	51	92·73
Use of Winnowing Fan	—	4	5	3	3	4	1	1	25	45·45
Tractor Threshing	9	16	9	3	1	6	1	1	45	81·92
Tractor Transport	—	8	4	2	—	1	—	1	17	30·10
Rice Milling	16	36	2	—	—	—	—	—	54	98·18

TABLE A3.—Use of Agricultural Machinery*

		Farmers No.	Reporting Per cent.	Av. No. of days per Reporting Farm per season	Av. Price per acre in Rs.	Av. Total Cost per Reporting Farm per season in Rs.
AFTER HYV	*4-Wheel Tractor*					
	First Ploughing	31	56.36	1.64	50	165.50
	Second Ploughing and Puddling	10	18.18	1.25	35	165.50
	Threshing	39	70.91	1.5	30	97.58
BEFORE HYV	*4-Wheel Tractor*					
	First Ploughing	29	52.73	1.30	35	108.30
	Second Ploughing and Puddling	9	16.36	1.22	25	87.46
	Threshing	34	61.82	1.5	15	69.43
	Use of 2-Wheel Tractors after HYV	3	5.45	1.68	50	145.00
	Use of 2-Wheel Tractors before HYV	1	1.82	1	30	30.00
	Use of Sprayers after HYV	40	72.73	2.30	2	11.50
	Use of Sprayers before HYV	16	29.09	1.33	1	2.63

* Compiled from data reported for Maha, 1970/71.

TABLE A4.—Labour Requirements for Paddy Production in Man Days per Acre in Pre-HYV and PostHYV Times*

	Operation	*Family Labour*		*Hired Labour*		*Exchange Labour*		*Total Man Days*	
		Pre-HYV	*Post-HYV*	*Pre-HYV*	*Post-HYV*	*Pre-HYV*	*Post-HYV*	*Pre-HYV*	*Post-HYV*
PREPARATORY TILLACE	(*a*) Preparation of bunds and cleaning channels	3.48..	3.87..	1.5 ..	2.37..	1.79..	1.83..	6.78..	8.07
	(*b*) 1st Ploughing ..	2.98..	3.04..	1.60..	1.23..	1.55..	0.72..	6.14..	5.00
	(*c*) 2nd Ploughing ..	2.78..	2.27..	0.81..	0.85..	0.75..	0.39..	4.34..	3.51
	(*d*) Puddling and Levelling ..	2.60..	2.28..	0.81..	0.91..	0.71..	0.26..	4.12..	3.45
	(*e*) Other ..	0.31..	0.32..	— ..	— ..	— ..	— ..	0.31..	0.32
	Sowing ..	0.78..	0.19..	— ..	— ..	— ..	— ..	0.78..	0.19
TRANSPLANTING	(*a*) Nursery Preparation	0.01..	0.71..	— ..	0.01..	— ..	— ..	0.01..	0.71
	(*b*) Removal from Nursery ..	0.08..	1.92..	— ..	2.08..	— ..	0.24..	0.08..	4.24
	(*c*) Planting Out ..	0.15..	1.30..	— ..	4.51..	— ..	0.37..	0.15..	6.19
CULTURAL OPERATIONS	Weed Control ..	1.87..	2.96..	1.33..	3.64..	0.57..	0.54..	3.77..	7.14
	Fertilizer Application ..	0.40..	1.18..	— ..	— ..	— ..	— ..	0.40..	1.18
	Spraying and Dusting ..	0.15..	0.48..	— ..	0.41..	— ..	— ..	0.15..	0.89
	Irrigation ..	2.18..	2.71..	— ..	— ..	— ..	— ..	2.18..	2.70
HARVEST and POST HARVEST OPER.	Harvesting and Collection ..	6.27..	7.55..	2.96..	3.83..	2.67..	1.69..	11.91	13.07
	Preparation of Threshing Floor ..	0.72..	0.81..	— ..	— ..	— ..	— ..	0.82..	0.81
	Threshing ..	3.49..	4.32..	1.26..	1.46..	0.98..	0.59..	5.75..	6.36
	Winnowing and Bagging	1.94..	2.24..	0.68..	1.11..	0.22..	0.12..	2.84..	3.47
	Transport ..	0.73..	0.92..	0.08..	0.22..	— ..	— ..	0.81..	1.14
	Total ..	31.03	39.06	11.05	22.63	9.25	6.75	51.34	68.44

* Calculated for the Maha season, 1970/71.

TABLE A5.—Paddy Yields per Acre, 1966/67–1970/71

Year	Average Yield Bu. per acre	Distribution of Yields in Bushels per Acre < 30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	> 100
1966/67										
Maha	44·10*	7·41%	40·74%	31·48%	18·52%	1·85%	—	—	—	—
Yala	33·45*	33·33%	61·11%	5·56%	—	—	—	—	-	—
1967/68										
Maha	50·92 (14·38%)	1·85%	22·22%	31·48%	29·64%	11·11%	3·70%	—	—	—
Yala	36·18 (9·18%)	18·52%	61·11%	16·67%	3·70%	—	—	—	—	—
1968/69										
Maha	60·32 (34·42%)	—	14·81%	18·52%	18·52%	27·78%	16·67%	—	1·85%	1·85%
Yala	41·38 (23·76%)	9·26%	50·0%	11·11%	11·11%	1·85%	1·85%	—	—	—
1969/70										
Maha	68·24 (53·42%)	—	5·56%	18·52%	18·52%	18.52	24·07%	11·11%	5·56%	1·85%
Yala	48·37 (43·46%)	3·70%	35·19%	16·67%	16·67%	5·56%	9·26%	—	—	—
1970/71										
Maha	70·96 (59·03%)	—	3·70%	12·96%	12·96%	24·07%	27·78%	12·96%	5·56%	—
Yala	55·41 (58·84%)	3·70%	24·07%	25·93%	25·93%	14·81%	7·40%	1·85%	1·85%	—

* Indicates the base year on which the per-centages have been calculated.

TABLE A6.—Total Lowland Paddy Production, 1966/67–1970/71

	1966/67 (*Pre-HYV*)		1967/68		1968/69		1969/70		1970/71 (*Post-HYV*)	
	Maha	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*
Area Sown in Acres ..	3·60..	3·53..	3·60..	3·56..	3·46..	3·42..	3·42..	3·42..	3·46..	3·38
Amount of Seed used in bushels..	7·17..	7·06..	6·50..	6·98..	5·07..	6·54..	4·06..	5·89..	3·85..	5·03
Average Production per farm in bushels	158·50..	118·15..	183·87..	128·83..	210·85..	141·57..	235·98..	165·50..	245·51..	187·52
Gross Returns in Rs. ..	2,193·52..	1,655·65..	2,516·52..	1,801·37..	2,914·43.	2,151·70..	3,313·19..	2,294·83..	3,442·56..	2,721·30

TABLE A7—Income Strata of Lowland Paddy Cultivators

Income Group 1,000 *Rs.*	*Pre-HYV* (*Cropping Year* 1966/67) *No.*	*Percent.*	*Post-HYV* (*Cropping Year* 1970/71) *No.*	*Percent.*	*Acreage*
1,001-1,500	3	5.65	1	1.85	1.0
1,501-2,000	7	12.96	2	3.70	2.75
2,001-2,500	4	7.41	6	11.11	2.0
2,501-3,000	9	16.67	2	3.70	1.75
3,001-3,500	3	5.56	3	5.56	2.17
3,501-4,000	5	9.26	1	1.85	2.50
4,001-4,500	4	7.41	6	11.11	2.67
4,501-5,000	4	7.41	4	7.41	2.88
5,001-5,500	5	9.26	3	5.56	2.67
5,501-6,000	4	7.41	4	7.41	3.38
6,001-6,500	4	7.41	2	3.70	3.50
6,501-7,000	1	1.85	2	3.70	4.00
7,001-7,500	—	—	—	—	—
7,501-8,000	—	—	2	3.70	4.5
8,001-8,500	—	—	3	5.56	5.0
8,501-9,000	—	—	2	3.70	4.5
9,501-10,000	—	—	2	3.70	5.0
10,001-10,500	—	—	1	1.85	5.0
10,501-11,000	—	—	2	3.70	5.0
11,001-11,500	—	—	2	3.70	5.0
11,501-12,000	1	1.85	2	3.70	5.0
12,001-12,500	—	—	—	—	—
12,501-13,000	—	—	1	1.85	5.5
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16,001-16,500	—	—	1	1.85	10.0

TABLE A8.—Income from Paddy Cultivation — Maha, 1970/71

	Value per Farm in Rs.	*Value per Acre in Rs.*
1. Gross Income	3,442.55	994.96
2. (*a*) Cost of Production (without imputing a value for family labour)	1,616.21	482.03
(*b*) Cost of Production (with imputed cost of family labour)	2,065.52	596.97
3. Net income under condition (*a*)	1,826.34	512.93
Net income under condition (*b*)	1,281.41	397.99
4. Net income from a bushel of paddy under condition (*a*)	Rs. 7.22	
Net income from a bushel of paddy under condition (*b*)	Rs. 5.60	

Note.—Cost of Production includes only purchased imputs.

TABLE A9.—Production on Lands Rented/Leased/Mortgaged, 1970/71

	Maha, 1970/71	*Yala*, 1971
1. Area sown in acres per reporting farm	1.94*	2.03*
	2.75†	2.75†
2. Amount of seed used in bushels per reporting farm	2.42*	4.14*
	3.63†	4.75†
3. Production in bushels per reporting farm	108.39*	88.50*
	158.75†	122.50†
4. Average Yield in Bushels per acre	55.87*	43.60*
	57.73†	44.55†
Disposal of Produce		
5. Seed for next cropping year in Bushels	4.87*	4.29*
	4.17†	5.00†
6. Sales per reporting farm in bushels	49.83*	38.75*
	156.25†	120.0†
7. Share to landlord in bushels	52.50*	42.39*
Share to landlord in cash	Rs. 225.00†	Rs. 241.67†

Note.— * Indicates lands rented on a share-cropping basis.
† Indicates lands leased or mortgaged.

TABLE A10.—Share of Incomes to Landlords/Tenants per Acre in Rs.

	Pre-HYV 1966/67	*Post-HYV* 1970/71
Gross Income	853.23	1,392.10
Tenants Share	429.11	671.29
Value of Seed Paddy @Rs. 16/bu.	68.83	53.01
Value of Fertilizer provided by landlord	—	19.24
Other charges paid by landlord	57.57	71.54
NET INCOME TO LANDLORD	306.72	596.34
NET INCOME TO TENANT*	135.72	225.99

* The cost of production in the two periods has been assumed to be Rs. 181.00 and Rs. 512.93 respectively in the Pre-HYV and Post-HYV periods.

TABLE A11.—Composition of the Means of Livelihood for an Average Farm, Maha — 1970/71

Source of Livelihood	*Activities or Enterprises*	*Average Gross Income in Rupees*	*Percentage share of Total Incomes*	
1. Crop Production				
Paddy	(*a*) Lowland Paddy (Ownland)	3,442·56	69·29	
	(*b*) Highland Paddy (Chena and Ownland)	213·05	4·29	
	Rent (Income as a tenant)	97·29	1·96	
	(Income as a landolrd)	24·24	0·49	
Other Cereals	Maize and Kurakkan	20·69	0·42	
Important Subsidiary Crops	Green chillies, Dry chillies, B. onions, R. onions	99·78	2·01	13·73
Root Crops	Manioc, Sweet Potatoes and Yams	8·00	0·16	
Legumes	Gingelly, Cowpea, Groundnut, Green Gram	16·52	0·33	
Vegetable Crops	All types	53·45	1·08	
Cash Crops	Tobacco	38·18	0·77	
Permanent Crops	Murunga, Banana, Coconut, Mango, Orange	112·05	2·26	
2. Livestock Production	(*a*) Egg Production	57·28	1·16	
	(*b*) Milk Production	79·25	1·60	4·77
	(*c*) Sales of Animals (Neat Cattle, Buffaloes and Poultry)	99·80	2·01	
3. Off-Farm Income	(*a*) Transport	52·73	1·06	
	(*b*) Trade	145·44	2·93	
	(*c*) Hiring	238·09	4·79	12·21
	(*d*) Activities involving capital investment	92·73	1·87	
	(*e*) Other occupations	77·27	1·56	
	TOTAL AVERAGE GROSS INCOME	4,968·41	100·00	

TABLE A12.—Disposal of Farm Produced Paddy, 1966/67–1970/71

	1966/67		1967/68		1968/69		1969/70		1970/71	
	Maha	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*	*Maha*	*Yala*
Seed for next season in bushels	9.82	9.61	9.91	9.89	9.41	9.30	9.19	8.94	9.26	8.96
Sales in bushels	108.9	72.07	131.57	84.28	157.91	97.26	184.65	111.00	185.04	133.06
Subsistence Requirements in Bushels	37.78	35.57	38.69	37.43	41.67	38.49	44.24	41.15	46.07	43.59
Given to Friends and Relatives	—	—	—	—	5.00	—	4.00	4.00	2.00	—

TABLE A13.—Changes in Fixed Capital in Farming

Type of Fixed Capital	Purchased or Constructed	Percent of Reporting Farms	Average of All Farms	Percent Purchased: Before 1960	1961-63	1964-66	1967-69	1970 and After
Draught Power	Purchased	40.00	—	—	—	—	—	—
	Shared	5.96	2.49	21.82	7.27	5.46	9.09	7.27
	Inherited	—	7.27	—	—	—	—	—
Mammoties	Constructed	9.00	3.69	100.00	1.82	1.82	5.46	89.09
	Purchased	80.00						
Wooden Ploughs	Constructed	53.36	1.51	100.00	—	—	27.27	45.46
	Purchased	9.09						
Metal Ploughs	Constructed	5.46	0.51	—	1.82	—	12.73	20.00
	Purchased	27.27						
Disc Harrows	Purchased	7.27	0.07	—	—	1.82	1.82	3.64
Carts	Constructed	5.46	0.09	1.82	1.82	1.82	3.64	—
	Purchased	3.64						
2-Wheel Tractor	Purchased	10.91	0.11	—	—	—	3.64	7.27
4-Wheel Tractor	Purchased	5.46	0.06	—	1.82	—	3.64	—
Crop Sprayers	Purchased	5.46	0.06	—	—	1.82	1.82	1.82
Weeders	Purchased	7.27	0.07	—	—	1.82	5.46	—
Seeders	Purchased	1.82	0.02	—	—	—	1.82	—
Gunny Bags	Purchased	98.18	54.55	Purchased Annually				
Winnowing Fan	Purchased	14.55	14.55	—	—	1.82	9.09	3.64
Irrigation Wells	Constructed	54.55	0.58	34.5	3.64	9.19	9.09	1.82

TABLE A14.—Domestic Technology

Item	*Per cent Reporting at Present*	*Before* 1950 *Per cent Reporting*	1951-60 *Per cent Reporting*	1961-63 *Per cent Reporting*	1964-66 *Per cent Reporting*	1967-59 *Per cent Reporting*	1970 *and After Per cent Reporting*
Sewing Machine	43.64	1.82	18.18	—	7.27	7.27	9.09
Radio	41.82	—	7.27	—	10.91	7.27	16.36
Petrol Lamp	80.00	—	18.18	16.36	23.64	18.18	3.64
Kerosene Cooker	1.82	—	—	—	1.82	—	—
Lanterns	85.66	—	—	—	7.27	20.00	58.18
Wrist Watch or Wall Clock	78.18	1.82	12.73	7.27	16.36	29.09	10.91
Bicycle	34.55	—	—	1.82	10.91	9.09	12.73
Coal or Electric Iron	32.73	—	7.27	5.46	3.64	10.91	5.46
Hand Pump	1.82	—	—	—	—	—	1.82
Automobile	1.82	—	—	—	1.82	—	—

Field investigations on the control of "Late Blight" of Potato

I. Screening of Fungicides.

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Results of three fungicide screening trials against the late blight of potato carried out at Sita Eliya are reported. Of the sixteen proprietory products tested Manzate D, Vondozeb and Difolatan 80 W were found to be very promising. Some of the fungicides which have been shown to be promising in previous trials were found to be breaking down in their efficacy. As such, the necessity to carry out regular and requent fungicide screening trials against late blight is strongly indicated.

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INTRODUCTION

The economic importance of the late blight disease of potato (*Phytophthora infections* (Mont. de Bary) in Sri Lanka has been discussed in several papers (Peiris & de Silva, 1954; Abeygunawardena & Peiris, 1958; Abeygunawardena, 1960; Abeygunawardena and Balasooriya, 1961; Caesar & Ganesan, 1963, and Seneviratne, 1970). The need to adopt chemical measures of control despite varietal resistance to this disease has been indicated by all these authors.

Seneviratne (1970) found several dithiocarbamate fungicides to be very promising against late blight. Out of these fungicides Antracol, Dithane M-45 and Manzate D are commonly used by potato cultivators in the hill country districts. In the trials described in the present paper these three standard fungicides, together with Brestan 60, were compared with some of the more recently introduced dithiocarbamate and other organic fungicides (Table 1).

EXPERIMENTAL METHODS

The trials were conducted during the period Yala 1971 to Maha 1972-73 at the Agricultural Research Station in Sita Eliya (1900 m). The potato variety "Arka" was used in all the trials.

In the first trial, carried out during Yala 1971, fifteen fungicides (Table 2) were screened using a square lattice design with five replicates. On the basis of the results obtained from this trial a few fungicides were selected for further screening in trials carried out during Maha 1971-72 and Maha 1972-73, using randomized complete block designs with four replicates.

The plot size for all three trials was 360 cm. × 450 cm. and included a 30 cm. bund and 30 cm. drain thus making the total planting area per plot 300 cm. × 450 cm. Ninety tubers were planted per plot. in ten rows, on a spacing of 45 cm. between rows and 35 cm. within a row. A single basal dressing of Sulphate of ammonia 560 Kg/ha, Conc. superphosphate 840 Kg/ha, Muriate of potash 150 Kg/ha and cattle manure 12.5 m/ha was applied just before planting.

The fungicides were applied on a 10 day schedule, using a high volume knapsack sprayer, at concentrations recommended by the manufacturer. Moveable screens were used during spraying to prevent spray drift. The first spray application was made 35-40 days after planting, and in all three trials no late blight infection was observed at the time the first spraying was carried out.

Late blight infection assessments, based on the B. M. S. Key (Anon., 1947), were taken at 7-10-day intervals beginning 4 weeks after planting.

RESULTS

Yala 1971 Trial: Although there was no late blight infection observed at the time of the first spraying a severe outbreak of the disease occured about the sixth week after planting with the onset of monsoonal rain and strong winds. An average degree of infection of 45% (at 8 weeks) was recorded even with the fungicide which gave the best degree of control in the trial. As a result yields were found to be relatively poor in all the treatments in the trial. The course of development of blight infection in the control treatment, in relation to weather, is shown in Fig. 1. Phytotoxic symptoms were observed only with the fungicide Brestan 60.

Relatively good control was achieved with following fungicides which gave significantly better yields (at 5% level) than the check treatment (Table 2) : Vondozeb, Harrison's Zineb 65 WP, Manzate D, Wopromanzin, Dithane M-45, Antracol and Difolatan 80 W. There was no significant difference between Vondozeb, Harrison's Zineb 65 WP and Manzate D in regard to their efficacy in controlling the disease.

Maha 1971/72 trial: Unlike in the Yala 1971 trial the degree of late blight infection remained relatively low in all treatments till about the tenth week after planting when, with the onset of very humid weather, the level of infection rose abruptly to nearly 100% in the control plots. The relationship between the development of blight infection and weather is shown in Fig. 2. Wtih the exception of Antracol satisfactory and significant control in terms of yield was achieved with all the fungicides tested, and there was no significant difference (5% level) between the fungicides which showed promise (Table 3).

Maha 1972/73 trial: Owing to the relatively dry weather conditions prevalent during the first two months of the crop the degree of blight infection remained very low till about the ninth week after planting (Fig. 3). All the fungicides tested gave satisfactory and significant control of the disease. Manzate D was significantly better (5% level) than the rest of the fungicides tested excepting Vondozeb. There was no significant difference between Manzate D and Vendozeb (Table 4).

DISCUSSION AND CONCLUSION

Surveys carried out recently in the Badulla and Nuwara Eliya Districts have shown that bacterial wilt disease caused by *Pseudomonas solanacearum* is becoming an increasingly important factor which would greatly limit the cultivation of potato in these two districts. The only means of control of this disease available at present is the use of long crop rotations. This method, however, is very rarely practised by our local cultivators. Therefore, as pointed out by Seneviratne (1970) the need to eliminate losses from late blight as far as possible by using very effective and economical measures of control is strongly indicated

The chief object of the studies reported in this paper was to select a few fungicides which would give adequate control of the disease. In general the organic fungicides, particularly the dithiocarbamates, were found to be superior to the copper based fungicides tested. Manzate D gave the best degree of control in two out of the three screening trials. Other fungicides which showed consistent results were Vendozeb and Difolatan 80 W. These fungicides together with a few others which had been regularly used hitherto against late blight were further tested in trials designed to find the optimum dosage, frequency and timing of fungicide application. These trials are reported in part II of this paper and the economics of control in the light of findings from these trials is discussed.

From the results obtained in the Yala 1971 trial it is apparent that under weather conditions which greatly favour late blight infection it is difficult to achieve satisfactory control of the disease with a ten-day spraying schedule even if the first spray application is made between 25-35 days after planting and before the onset of infection as suggested by Seneviratne (1970). Such weather conditions characterized by moderate rains, mist, strong winds and relatively little sunshine are almost regularly experienced from about May to August in the Nuwara Eliya District. A much more frequent application of fungicides may perhaps give better control of the visual symptoms of the disease. However, considering the relatively poor yields obtained particularly owing to the physically damaging effects of severe blowing on the growth of the crop it is doubtful whether such frequent application of fungicides would serve any useful purpose. As such it seem more advisable to avoid the cultivation of potato in the Nuwara Eliya District during the period May to August.

It is apparent from the results obtained in the screening trials that the efficacy of at least some of the fungicides which had hitherto shown promise in controlling late blight are now breaking down gradually. It is possible that the very wide use of these fungicides in the recent past by cultivators had led to the appearance of new strains of the pathogen which are apparently resistant (Sisler & Cox, 1960) to these fungicides. Such breakdown in efficacy with time obviously indicates the necessity to carry out more frequent and regular fungicide screening trials against the late blight disease.

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TABLE I.—Fungicides tested

Fungicide	*Active Ingredient*	*A.I.(%)*
Antracol	Zinc propylene bisdithiocarbamate (propineb)	70
Bayer Maneb	Manganese ethylene bisdithiocarbamate (maneb)	70
Benlate	1– (buthlcarbamoyl)– 2– benzimidazole carbamic acid methyl ester	50
Brestan 60	triphenyl tin acetate+maneb	60+20
Cupravit Ob 21	copper oxychloride	50
Difolatan 4F	cis–N– (1, 1, 2, 2, tetrachloroethyl) thier– cyclohexene– 1, 2– dicarboximide	39
Difolatan 80W	do.	80
Dithane M45	complex of zinc and maneb (mancozeb)	80
Manzate D	maneb with zinc	80
Mildrex	zineb+copper oxychloride	
Miltex	do.	
Perenox	cuprous oxide	50
Tiexine	zinc ehtylene bisdithio carbamate (zineb)	80
Vondozeb	Complex of zineb and maneb	80
Wopromanzin	Maneb+ zinc. compound	80
Wopromanzin Supra	do.	80
Zineb 65 W. P. (Harrison's)	zineb	65

TABLE 2.—Effect of fungicides on the contol of late blight

YALA 1971—TRIAL

Planted on 8.5.71.

Sprayed on—7.6, 17.6, 26.6., 6.7 and 16.7

Fungicide	*Rate/1,000 l*	*Mean%blight at 8 weeks*	*Mean yield metric tons/ha*
Vondozeb	2 Kg	45.0	4.68
Harrison's Zineb 65 WP	2 Kg	71.0	3.55
Manzate D	2 Kg	50.0	3.42
Benlate+Manzate D	0.5 Kg–1 Kg	74.4	3.34
Wopromanzin	2 Kg	70.0	3.32
Dithane M–45	2 Kg	66.0	3.07
Antracol	2 Kg	65.0	3.02
Miltex	2 Kg	69.0	3.99
Difolatan 80 W	1.25 Kg	73.0	2.82
Cupravit Ob 21	6.5 Kg	80.0	2.52
Midrex	2 Kg	75.0	2.46
Percnox	6.5 Kg	77.0	2.14
Brestan 60	0.4 Kg	82.0	1.86
Difolatan 4F	4.21 Kg	80.0	1.81
Benlate	0.5 Kg	90.6	1.40
Control	—	98.0	1.52
L.S.D. (P.=0.05)			1.30

TABLE 3.—Effect of fungicides on the control of late blight

MAHA 1971/72 TRIAL

Planted on : 16.9.71

Sprayed on : 23.10, 3.11, 13.11, 23.11, 3.12, 14.12 and 23.12.

Fungicide	*Rate/1000 l*	*Mean % blight at 10 weeks*	*Mean yield metric tons/ha*
Manzate D	2 Kg	20.0	14.49
Vondozeb	2 Kg	23.8	12.83
Dithane M—45	2 Kg	23.8	12.55
Difolatan 80 W	1.5 Kg	33.8	12.30
Wopromanzin	2 Kg	32.5	12.22
Harrison's Zineb 65 WP	2 Kg	25.0	11.22
Antracol	2 Kg	52.3	10.26
Control		73.75	7.52
L.S.D. (P=0.05)			3.70

TABLE 4.—Effect of fungicides on the control of late blight

MAHA 1972/73 TRIAL

Planted on : 9.8.72

Sprayed on : 9.9, 19.9, 29.9, 9.10, 19.10, 29.10 and 7.11.

Fungicide	*Rate / 1000 l*	*Mean % blight at 10 weeks*	*Mean yield metric tons/ha*
Manzate D	2.5 Kg	5.4	25.17
Vondozeb	2.5 Kg	15.4	22.43
Difolatan 80 W	1.5 Kg	18.4	21.31
Bayer Maneb	2.5 Kg	11.0	21.08
Wopromanzin Supra	2.5 Kg	18.6	21.06
Difolatan 4 F	5.61 l	21.3	20.92
Tiezine	2.5 Kg	56.2	19.88
Antracol	2.5 Kg	51.5	17.65
Dithane M—45	2.5 Kg	51.2	15.27
Control		98.5	9.85
L.S.D. (P=0.05)			3.50

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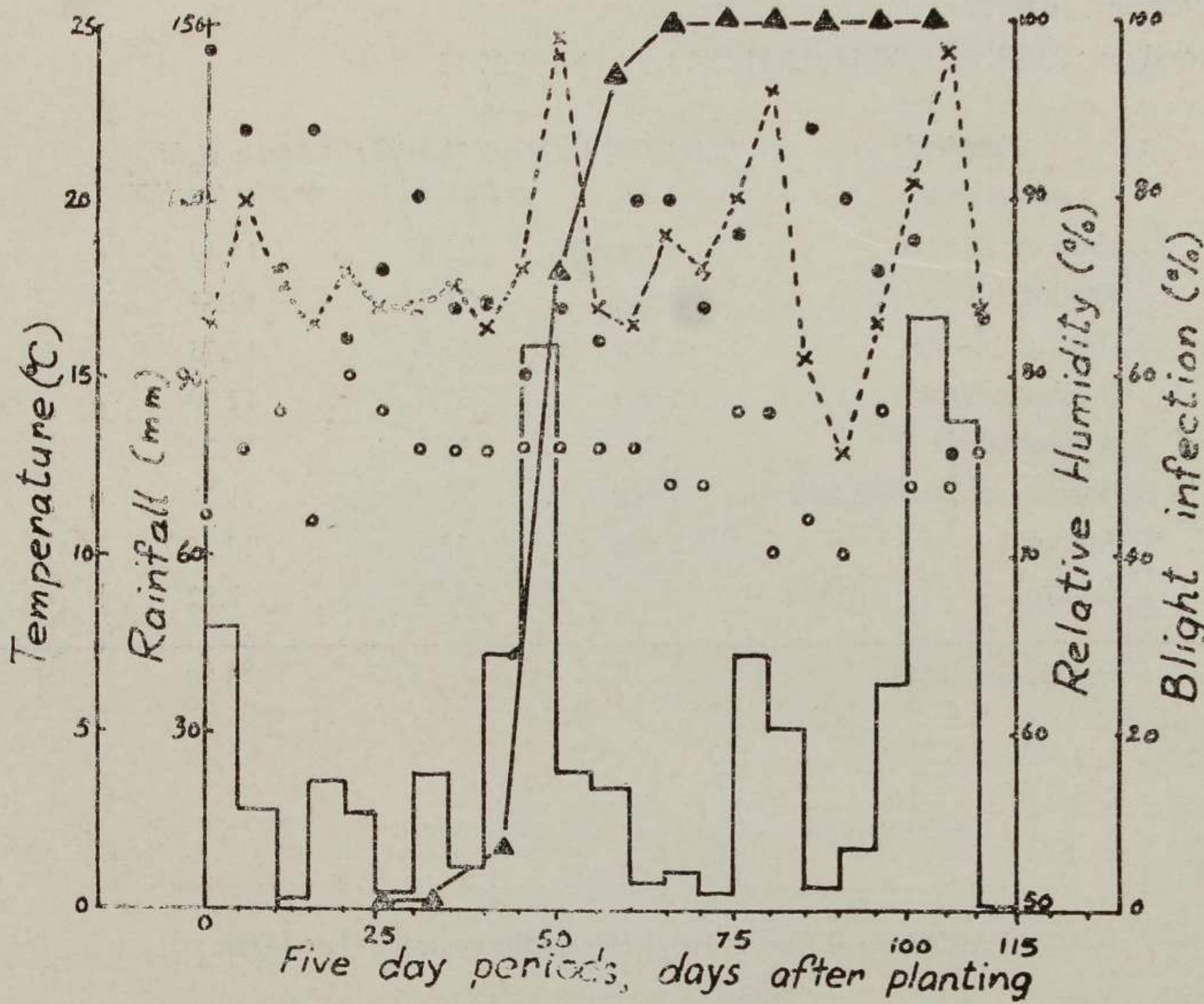
Fig. 1.—Blight infection and weather conditions during the Yala 1971 trial for five day p riods from the time of planting.



x- - -x- - -x Average relative humidity

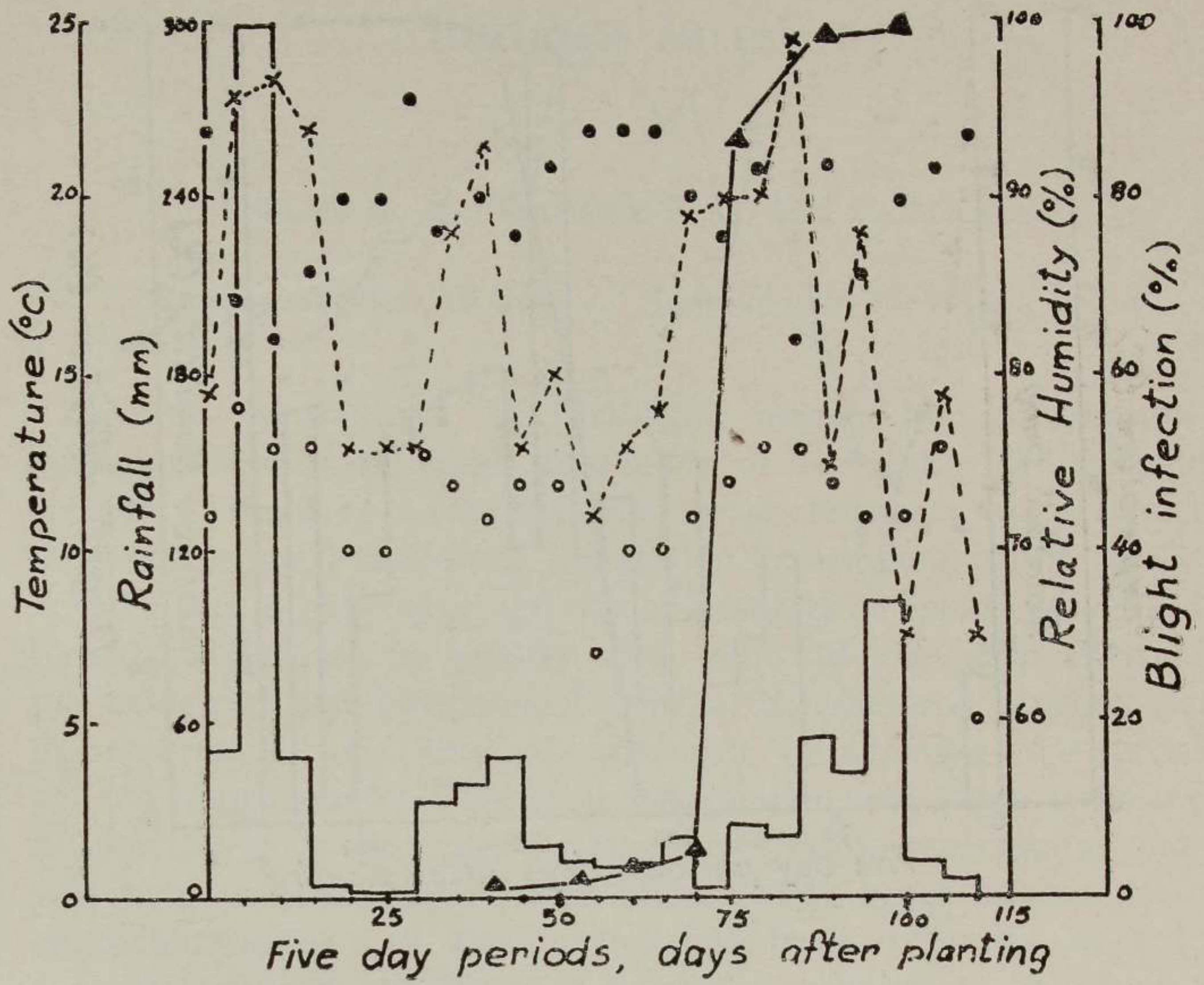
△——△——△ Blight infection in control treatment

• • • Maximum temperature

o o o Minimum temperature

Histogram : indicate total rainfall for 5 day periods

Fig. 2 Blight infection and weather conditions during the Maha 1971/72 trial for five day periods from the time of planting.



X---X---X Average relative humidity

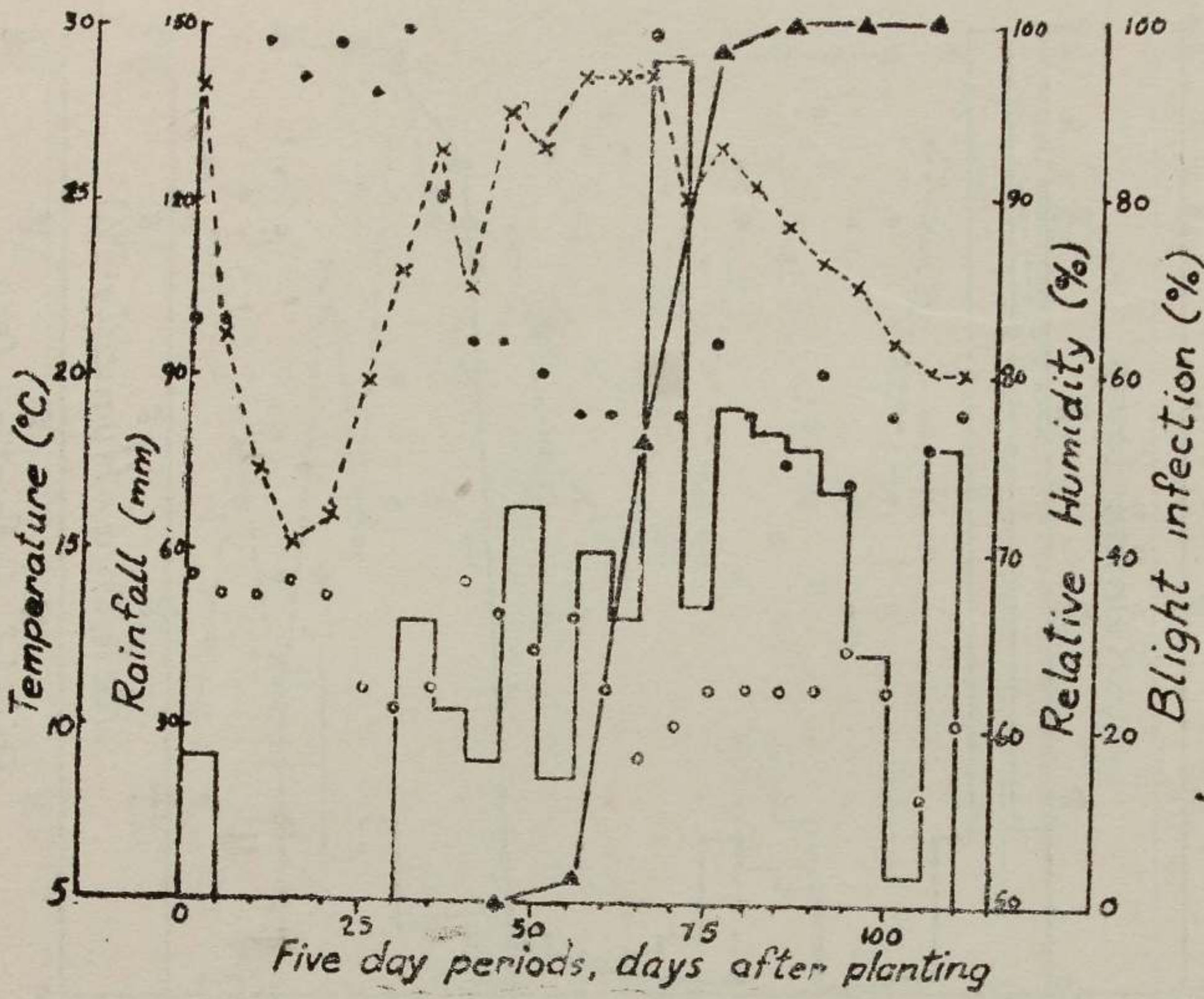
Δ—Δ—Δ Blight infection in control treatment

• • • Maximum Temperature

o o o Minimum Temprature

Histogram: indicate total rainfall for 5 day periods.

Fig. 3. Blight infection and weather conditions during the Maha 1972/73 trial for five day periods from time of planting.



Average relative humidity

Blight infection in control treatment

Maximum Temperature

Minimum Temperature

Histogram : indicate total rainfall for 5 day periods

Physiological studies of radiation-induced mutants in gram

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INDUCING MUTATIONS by artificial means like irradiation or mutagans results in wider frequency of variability which helps a breeder to build up a raw material for evolutionary improvement of economic crops Pre-sowing irradiation treatments result mostly in initial shifts in enzymatic activity and metabolic events which in turn result in increase in quality and yield of the crop Studies on physiologicial and biochemical aspects of irradiated progeny helped in evoking a new line of approach in tackling the problems of crop improvement. This basic information will serve as an indices in selecting good ideotypes for further breeding programme, and also will help to retain apparently undersirable types having desirable characteristics as well. The physiological basis of increase in desirable characteristics due to effects of irradiation remains to be investigated in most of the economic crops in view of above the studies were carried out to know the changes in physiological and growth components of six gram mutants as affected by gamma irradiation in RT generation.

MATERIALS AND METHODS

Air dried seeds of gram varities viz. N—59, N—31, Chaffa and Dacca were treated with 15, 30 and 45 KR doses of gamma irradiation in September, 1965. Few new morphological distinct mutants were isolated in R_3 generation. True breeding nature of mutants was isolated in R and R_3 generation and was confirmed in R_4 to R_7 generations. Six mutants, viz. N—59, big leaf, N—31, very big leaf, Chaffa, big pod, Dacca bipinnate, Dacca elongated and Dacca white flower were isolated from irradiated progeny of 15 KR 30, 40, 15, 30 and 15 KR doses respectively, the seeds of which were sown in 1971—72 during *rabi* season along with their respective controls in single rows. The observations with respect to stomatal frequency, index, length of leaf epidermal hair, maximum leaf thickness, leaf water content, leaf chlorophyll content and leaf respiration were recorded under laboratory conditions. Stomatal number was counted from four miscroscopic fields and average was recorded. The rate of respiration of leaf samples from growing region was determined with Pittenkofer's continuous gas current flow method (Mayer *et al.*, 1955) and expressed as mg. C_g 10 gm/hr at 26° C temperature. For estimation of crude protein content of seed, the ground seed sample was analysed in triplicate, for nitrogen content and percentage nitrogen was multiplied by 6.25 factor. The total chlorophyll content was estimated by colorimetric proredure for pigment analysis (Snell & Snell, 1954).

During the year 1972-73, a replicated progeny row trial of irradiated gram mutants along with their respective controls was laid out in simple R. B. D. in order to know the changes in growth components such as 100 seed weight, number of seeds per plant that ultimately resulted in alteration of yield of gram mutants. Spacing was kept as 30 × 15 cm. The net plot size was 6.0 × 3.0 m. Two rows of each mutant along with checks were sown. At the time of harvest, the yield per plant (average of 5 plants) obtained from four replications was statistically analysed.

TABLE I·—Effect of Gamm Irradiation on leaf structure of Gram Mutants

Particulars	Gram Mutants						
	N-59	*N-31*	*Chaffa*	*Dacca*	*Dacca Bipinnate*	*Dacca Elongated*	*Dacca White flower*
	Stomatal Frequency/cm²						
Control	45455	39773	34091	62501	—	—	—
Mutant	34091	34091	39773	—	62501	28409	30491
	Stomatal Index						
Control	12·03	11·40	11·73	15·55	—	—	—
Mutant	12·79	15·50	12·08	—	7·69	15·71	15·66
	Length of leaf Epidermal hair mm.						
Control	0·382	0·253	0·309	0·300	—	—	—
Mutant	0·253	0·284	0·213	—	0·359	0·293	0·303
	Maximum leaf thickness in mm.						
Control	0·437	0·362	0·546	0·550	—	—	—
Mutant	0·508	0·466	0·562	—	0·437	0·450	0·470
	Leaflet Area mm²						
Control	36	135	24	24	—	—	—
Mutant	160	170	50	—	10	30	32

RESULTS AND DISCUSSION

The variability in phyisological components of gram mutants influenced by gamma irradiation are summarized in Table I, II & III.

I *Leaf structure :* The relevant data are given in Table I.

(1) *Stomatal frequancy and Index :* The data reveal that stomatal frequency is decreased in all the mutants except in chaffa big pod mutant where increase is noted by 14.28% as compared to the control. No change in stomatal number in Dacca bipinnate mutant was seen. Similarly stomatal index is increased in all mutants except in Dacca bipinnate where it is reduced by 7.86% over control. Roy and Clark (1970) also reported significant increase in stomatal index in X-ray irradiated plants of *Vicia faba.*

(2) *Length of leaf epidermal hair :* The length of leaf epidemal hair has been reduced in mutants of N-59, Chaffa big pod and Dacca elongated but it is highly increased in N-31 and daca bipinnate. A significant reduction in length and density of leaf hair in two wheat species reported by Kapoor *et al.* (1965) supports the above finding. Hairy leaf helps in better foliar absorption of minerals and water. In addition, developed leaf hair induces the tolerance to certain pests. Increase in length of leaf hair recorded in mutants of N-31 very big leaf and Dacca bipinnate by 0.031 and 0.059 mm. respectively may be useful for foliar absorption.

(3) *Leaf thicknes sand leaf area :* It is obvious from the data that the leaf thickness is increased in mutants of N-59, N-31 and Chaffa but decreased in all the three mutants of Dacca. The increase ranged from 0.016 to 0.104 mm. as compared to their respective controls. Similarly the findings of Vlasynk and Sil'chenko (1964) as regards increase in size and volume of cells of mesophyll of sugar-beet and fibre flax due to X-ray treatment support the results of present investigations. They further observed that insufficiently utilized assimilates retained in mesophyll cells increased thickness causing diminished yield. However, in present studies increase in thickness of leaf blade in general increased the yield of gram mutants.

II *Physiological studies :* The data on these pertinant observations are presented in Table II.

TABLE II—Physiological studies of radiation-induceed mutants in Gram

Particulars	*Gram Mutants*						
	N-59	*N-31*	*Chaffa*	*Dacca*	*Dacca Bipinnate*	*Dacca Elongated*	*Dacca White flower*
	Leaf Respiration mg CO_2/10 gm/hr						
Control	6·16	3·08	5·72	6·16	—	—	—
Mutant	7·04	4·84	6·60	—	7·48	6·16	7·04
	Leaf Chlorophyll content (% Absorbance)						
Control	58	204	203	102	—	—	—
Mutant	208	222	112	—	90	187	201
	Per cent Crude Protein content of seed						
Control	21·58	23·80	—	21·00	—	—	—
Mutant	22·29	28·00	—	—	19·25	26·25	20·56
	Percent leaf water content						
Control	57·50	57·24	54·07	60·34	—	—	—
Mutant	59·10	58·07	64·71	—	60·00	61·66	46·11
	Colour of chlorophyll Extract						
Control	DY	FG	DG	YR	—	—	—
Mutant	DG	DG	YG	—	Yellow	FG	DY

DY=Deep Yellow ; DG=Dark Green ; FG=Faint Green ; YR=Yellowish Red ; YG=Yellow Green.

(1) *Leaf respiration* : The data indicate that the rate of leaf respiration increased in all the mutants as compared to their respective controls except in Dacca elongated mutant where no change was seen. Bogdashevskaya *et al.* (1967) also reported reduction in leaf respiration in winter rye at 2.5 and 5 KR 'Y' rays irradiation. Such an effect would be beneficial in increasing net grain of dry matter. Increased respiration in present studies suggests that the gamma irradiation resulted in an increase in initial shifts of enzymatic activity.

(2) *Leaf chlorophyl content* : Alteration of chlorophyll content of leaf affected by irradiation treatment is of common occurrence. The observation on chlorophyll content revealed that gamma irradiation considerably increased the chlorophyll content of leaf in mutants of N-59, N-31, Decca elongated and Dacca white flower, while in Chaffa

big pod and Dacca bipinnate ; it is found to be reduced. Pre-planting irradiation treatment also increased chlorophyll content in spring rye at low doses of X-ray (Bogdashevskaya and Runova, 1966) as well as in *Phaseolus vulgaris* (Sucin and Henegarin, 1967). However, reduction in chlorophyll content is also reported by Roy and Clark (1970) due to X-ray in *Vicia faba.*

It appears from the colours of the chlorophyll extract that the mutants of Chaffa, Dacca bipinnate and Dacca white flower contains more proportion of carotenoids and xanthophyll as compared with the chlorophyll a and b. As increase in chlorophyll content stimulate the food synthesis, this change may have significance in altering yield. However, Tai and Todd (1972) observed reduction in carotenoid contents of Lutescens mutants in ground nut as compared to those of normal in their chromatographic studies of pigment analysis.

(3) *Leaf water content :* The water content of the leaves is increased in all the mutants and ranged from 0.34 to 10.64% except in mutants of Dacca elongated and Dacca white flower. Increased water content results in maintaining the plant protoplasm always at high water potential.

(4) *Crude protein content in seed:* Negative as well a positive effect of irradiation regarding change in CPC are reported by many workers. Virughese and Swaminathan (1967) reported 2.5% increase in protein content in Sarbati-Sonora wheat as compared to Sonora-64 due to gamma ray treatment. Uprety (1968) also observed that 4 KR dose of gamma rays increased the protein content in *Vigna unguiculata.* In present studies also appreciable increase in CPC to the extent of 4.20 and 5.25% over control is observed in N-31 very big leaf and Dacca elongated mutants respectively. Very big leaf mutant of N-31 not only yielded 48.38% more over control but also found to contain 4.20% more protein in its grain and therefore, its cultivation will offer substantial gain to a farmer with respect to yield as well as protein. In a country like India where millions are suffering from malnutrition, such a type of mutant will certainly help to cater the needs of masses if cultivated on large scale. In addition, N-31 is early and hence it may stand better significance.

III *Growth components.*—The observations recorded on effect of gamma irradiation in trial of 1972-73 are summarized in Table—III and also graphically presented in figure 1.

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TABLE III—Effect of Gamma Irradiation on Growth Components of Gram Mutants

Particulars	Gram Mutants							
	N-59	*N*-31	*Chaffa*	*Dacca*	*Dacca Bipinnate*	*Dacca Elongated*	*Dacca White flower*	*Remarks*
				Number of seeds per plant				
Control ..	33·12..	14·81..	32·00..	43·57..	— ..	— ..	— ..	SE=4·37
Mutant ..	25·56..	24·37..	35·75..	— ..	44·62..	38·69..	56·25*..	CD=12 68
Percent increase/ decrease..	—22·82..	+64·55..	+11·71..	— ..	— 2·88..	—10·79	+29·69 ..	—
				100 Seed weight in gram				
Control ..	37·0 ..	37·0 ..	12·0 ..	15·0 ..	— ..	— ..	— ..	—
Mutant ..	28·0 ..	35·0 ..	22·0 ..	— ..	10·0 ..	12·0 ..	14·0 ..	—
				Mean Seed Yield per plant gm.				
Control ..	5·10..	4·65..	5·40..	5·60..	— ..	— ..	— ..	NS
Mutant ..	5·50..	6·90..	6·30..	— ..	3·95..	3·60 ..	6·05 ..	SE—0·866
Percent increase/ decrease..	+ 7·84..	+48·38..	+16·66..	— ..	—29·46..	—25·71	+ 8·03 ..	—

* Significant at 5% level. NS = Non-significant.

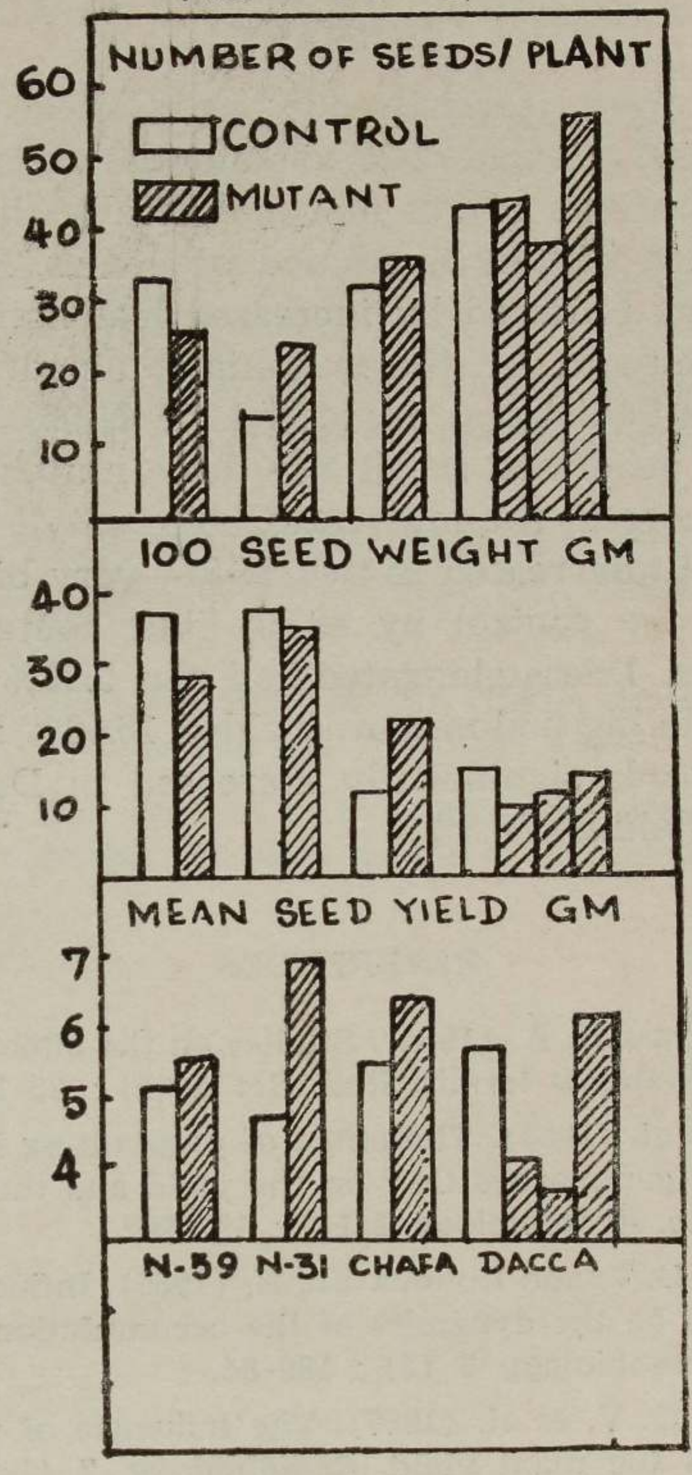
(1) *Number of seeds per plant.*—It is clear from the data that in case in Dacca white flower mutant there is only significant increase in number of seeds per plant as compared to its control, but in other mutants differences are non-significant. However, in general, increase in number of seeds per plant also correspondingly increased the grain yield of some mutants of gram. Though number of seeds of N-59 big leaf mutant is decreased by 22.82% the increase in yield is found to be 7.84% over control. This may be attributed to the maximum increase in leaf area (34.4%) followed by exceptional increase in chlorophyll content as well as leaf thickness.

In contrast to above increase in number of seeds by 2.88% resulted in reduction in yield by 29.46% in case of Decca bipinnate. This may perhaps be due to reduced leaf area and low chlorophyll content.

(2) *100 seed weight.*—The data reveals that 100 seed weight is highly reduced in most of the mutants as compared to their respective controls, Chaffa mutants bear big pods where they are greatly

increased. This shows that grain filling of Chaffa mutant is considerably increased which may be due to better translocation of photosynthates to the grain, Amer and Hakeem (1964) also reported slight decrease in 100 seed weight of *Lupinus termis* when it was treated with 4 to 12 KR and 20 KR gamma rays.

FIGURE-1



(3) *Mean seed yield.*—Statistical analysis revealed that the yield differences are not significant. However, marked increased in mean seed yield of gram to the extent of 7.84, 48.38, 16.66 and 8.03% over controls is observed in mutants of N-59 big leaf, N-31 very big leaf, Chaffa big pod and Dacca white flower. Both Dacca elongated and bipinnate yielded considerably less than their respective controls, the reduction being 25.71 and 29.46% respectively. This may be attributed

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to the thinness of leaf and greater proportion of yellow pigments in leaves. The increase in yield is also reported in potato (Berezina *et al.,* 1963) and castor (Shivraj and Raman rao, 1963). However, reduction in yield due to radiation has not been uncommon as reported in pea by Tselishchev *et al.* (1965) and in groundnut by Sanjeeviah *et al.* (1967) as well.

SUMMARY

Investigations were carried out at College of Agriculture, Parbhani, during 1971/72 and 72-73 to study the variation in physiology and growth components of six morphologically distinct mutants in gram, isolated from gamma irradiated progenies. Reduced leaf area and stomatal index followed by increased leaf hair was observed in Dacca bipnnate mutant. All the mutants retained more moisture in their foliages. Leaf thickness increased in N-59, N-31 and Chaffs mutants while it decreased in all the three mutants of Dacca. Leaf respiration was more in the mutants. Cholorophyll content increased in four mutants but decreased in two, N-31—very big leaf mutant not only out-yielded the control by 48.30% but contained 4.20% more protein in its grain. Dacca elongated had also 5.25% more protein but yielded less. Chaffa big pod mutant yielded 16.66% more than control The number of seeds significantly increased in Dacca white flower with increase in yield by 80.3%.

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Incompatibility in fruit plants—a review

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Self-incompatibility may be defined as the "inability of a plant producing functional gametes to set seed when self-pollinated" (Brewbaker, 1957). Incompatibility is a mating system in hermaphrodite plants in which gametes are functional but fail to produce zygotes on self and/or cross pollination. Both self and cross incompatibility involve some break in the mechanism between pollination and fertilization. The term "incompatibility" was first used by Stout (1917) but was first discovered by Kolreuter (1764, cited by Darwin, 1876). It is different from sterility which is lack of pollen production or/pollen is unable to function. It is also different from sterility in interspecific hybrids which is due to lack of homology. Most of the early workers (Scott, 1865 to East, 1940) referred to this phenomenon as "self-sterility". This incompatibility phenomenon is widespread in higher plants and is one of the serveral mechanisms which encourage outbreeding.

Incompatibility systems

Incompatibility has been classified in different ways :

1. Flower morphology (Lewis, 1949)
   - (*a*) heteromorphic, and
   - (*b*) homomorphic
2. Genetic control (Mather, 1944)
   - (*a*) Gametophytic, and (pollen control)
   - (*b*) Sporophytic (style control)

1. *Flower Morohology :*

(*a*) *Heteromorphic :* The heteromorophic incompatibility, first described by Darwin in 1877, is associated with differences in the lengths of styles and the levels of the anthers. The two kinds of flowers viz. pin with long style and short anthers and thrum with short style and long anthers are borne on different plants of the same species. Pollinations are compatible only between anthers and stigmas at the same height, i.e. between the pin and thrum and the reciprocal. Apart from heterostyly, the difference between the pin and thrum flowers are also exhibited in incompatibility reaction of style and pollen, size of the pollen grain (small in pin) and size of the stigmatic cells (large in pin). In other words, there is a complex of characters which differentiates the pin and the thrum flowers.

The genetic control of the characters complex in the distylic flowers is by a single S locus with two alleles. The thrum flower is heterozyguous (Ss), whereas the pin is homozygous recessive (ss). In thrum x pin matings, the progeny is 1 thrum (Ss) : I pin (ss). In the reciprocal mating of pin x thrum, the pollen behaves as if of S constitution resulting again in equal proportion of pin and thrum flowers in the progeny. The compatibility is thus determined by the sporophyte in which thrum is always dominant to pin. The crosses between the same types of flowers i.e. thrum x thrum or pin x pin are incompatible.

The S locus in distylic systems has been proposed by Lewis in 1954 to comprise three sub units : one unit controlling the stylar characteristics, second the anther height, and third for controlling the size and incompatibility of the pollen. The rare occurrence of homomorphic plants in this group may be explained on the basis of intra-locus crossing over.

A more complex type of heterosyly is found in which the sexual organs grow to three heights, viz. long, intermediate and short. The compatible unions are between the flowers having style and stamen at the same height. This system is controlled by two pairs of alleles : long style (aabb), short style (A—B and A—bb) and mid style (aaBB or aaBb) where A is spistatic to B and b. The anomalous genetic ratios obtained in this system are caused by tetraploidy.

In general, the heteromorphic incompatibility is sporophytic. The common features of the heterostylic species are :

(1) genetic control by small number of alleles,

(2) one allele is dominant to another,

(3) sporophytic incompatibility, and

(4) short style is always dominant to long.

(b) *Homomorphic :* In the homomorphic species, the mating types are of the same kind and can be distinguished only by appropriate breeding tests. The incompatibility systems of *homomorphic* species will be discussed under the second way of classification based on genetic control in pollen or style.

2. *Genetic Control*

The genetic control of incompatbility was independently postulated by Prell (1921), Lehman and Filzer (1926, cited in East, 1929) and East and Mangelsdorf (1925). The basic concent of their hypothesis called the oppositional allele hypothesis is that incompatibility is governed by an allelomorphic series of genes (S1-Sn) such that pollen tubes having a particular S—allele grow slowly (or are inhibited) in styles which carry the same allele and rapidly in those that do not. There are two kinds of genetic control of incompatibility namely gemetophytic and sporophytic.

(*a*) *Gametophytic determination:* The gametophytic control of incompatibility is determined by the genetic constitution of the pollen itself. This system is different from heterostyly in that the alleles have an independent action with dominance in the style. It is the most widespread having been recorded in over sixty Angiosperm families (Growe, 1964) including Solanseae, Onagraeae, Rosaceae, Gramineae, Leguminoseae and Scrophulariaceae.

The main features of this system are:

(1) A large multiple allelic series of one S-locus determine incompatibility (The number of S locus alleles is estimated to be 212 in *Trifollum,* 37 in *Oenothera* and 17 in *Nicotiana.* The high number of S alleles may arise through direct mutation through some balanced changes in the internal structure—an allele giving rise to a new one in several steps or through independent evolution (Pandey, 1957). These multiple alleles assure the perpetuation of a species through outbreeding);

(2) failure of pollen grain to germinate;

(3) growth of pollen tube so slow that it fails to reach the ovule;

(4) growth of pollen tube completely inhibited;

(5) *basic fact*—pollen tube unable to function in style in which the same S allele is present in pollen and style;

(6) control of pollen reaction is gametophytic, and

(7) alleles have individual action in the style without any interaction.

This system has three main types of pollination as follows:

Pollen grain — is haploid and has one S allele

Style — is diploid and has two S alleles.

Matings

Female		*Male*		*Reaction*
$S_1 S_2$	..	$S_1 S_2$	..	Incompatible
$S_1 S_2$	..	$S_1 S_3$	..	$S_1 S_3$ and $S_2 S_3$ (half incompatible)
$S_1 S_2$	..	$S_3 S_4$	..	$S_1 S_3$, $S_2 S_3$, $S_1 S_4$, and $S_2 S_4$ (compatible)

The important point is that the genotype of the female is never recovered in the progeny.

(*b*) *Sporophytic determination.*—In the sporophytic system of incompatibility, the specificity of the pollen is determined by the genotype of the parent (sporophyte). It was first descrbied by Gerstel in *Parthenicum argentatum* and by Hughes and Babcok (1950) in *Crepis foetida.* Since then, a similar system has been reported in many species of the Compositae (Crowe, 1954 ; Habura, 1957 ; Imrie and Knowles, 1971) Cruciferae (Bateman, 1954, 1955 ; Sampson, 1958, 1964 ; Thompson, 1957 ; Adamson, 1965) and Convolvulaceae (Hernandez and Miller, 1962, 1964 ; Martin, 1965).

In the sporophytic system complex relationship may exist among the alleles. The minimm requirement for this system is the presence of one locus with two alleles and dominance interaction (Lundqvist, 1969). The behaviour of S alleles in*Theobroma cacao* has been studied by Cope (1958, 1962) and Knight and Rogers (1955). It was found by Cope that in incompatible pollinations, fusion of the female and male gamete did not take place in 100%, 50% or most commonly, 25% of the ovules—and these degenerated. It appeared that the presence of these degenerating ' non fusion ' ovules led to the shedding of the flowers. Cope suggested that the S—gene acted at two stages : (*a*) the dominane relationship between alleles was imposed before meiosis, and (b) at fertilization, gametes carrying identical alleles which were dominant in the sporophyte (s) failed to fuse. In spite of this element of gametophitic control, Code accepted that *T. cacao* had a sporophytic type of incompatibility. It is evident that in the sporophytic system, the alleles may show independent action, dominance, on more complex action, providing a broad spectrum of genetic action.

The main features of the sporophytic system are as follows :—

(1) Incompatibility is controlled by a series of alleles at a single locus S ;

(2) S-alleles may act independently or show a dominance relationship in determining pollen behaviour. (If the former, the pollen will be inhibited by all styles in which either allele is active ; if the latter, only those in which the dominant allele is active ;

(3) reaction of the pollen is determined by both S-alleles in the sporophyte, all the pollen grains produced having a similar incompatibility reaction ;

(4) S-allele may act independently or show a dominance relationship in the style ;

(5) same alleles may show different dominance relationships in the style and pollen, leading to reciporcal differences in cross compatibility (Growe, 1954 ; Bateman, 1954) ;

(6) induction of autopolyploidy has no effect on the S-allele action in the sporophytic system. This may be due to the presence of two alleles at the time of S-allele action. In the gametophytic system, there are numerous examples to show that the auto-tetraploidy induces the breakdown of self-pollen creates in a new situation for the operation of monogenic gametophytic control where a competitive interaction between the alleles in the same pollen resulting in the breakdown of the mechanism.

Cytology of incompatibility system :

Scott (1965) was the first to observe slow pollen-tube growth on selfing *Oncidium* (incompatible system). Sears (1937) grouped the incompatible plants into three classes on the basis of the site of inhibition of pollen tubes in the style. These classes are briefly explained as follows :

(i) *Inhibition on the stigma :*

The pollen grains either show poor germination as *Linum grandiflorum* or the tubes fail to penetrate the stigma as in *Notylus*. Many species in the compositae, *cruciferae* and *gramineae* belong to this class.

Removal of a thin layer of stigma or even maceration of the stigmatic surface led to self-fertility in *Brassica oleracea* (Sears, 1937). This showed that the incompatibility barrier resides in the stigma of this species. Heiner and Linskens (1961) showed that in *Cardamine pratensis*, the cuticle of the stigma constitutes the barrier to the penetration by pollen tubes ; compatible pollen tubes enzymatically breakdown the cuticle, while incompatible ones do not produce this enzyme.

(ii) *Inhibition in the style :*

The behaviour of the tubes in the style varies considerably depending on species and environmental conditions. In *Nicotiana* incompatible tubes reach ovary with 7-8 days whereas compatible ones do so in 3-4 days. In Japanese pear, growth is normal to the base of style and then stopped.

(iii) *Inhibition in the ovary or ovules :*

Stout and Ghandler (1933) found that in *Hemerocallis citrina*, inhibition took place at the entrance to, or within the ovary. Cope (1962) reported that in *Theobroma cacao* a proportion of ovules do not fuse with the gametes which results in shedding of flowers. Brewbaker (1957) suggested that intimate contact between pollen tubes and stylar tissue is necessary for inhibition to occur. This view inhibited by the hollow styles of *Anona* and *Gasteria* (Brewbaker and Gorrez, 1967) and Ribes (Arasu, 1967).

The cytological studies on pollen by Brewbaker (1959) and Pandey (1960) have further shown that there is a correlation between pollen cytology and site of inhibition. The species in which the site of inhibition was on the stigma had trinucleate pollen, whereas those in which the site of inhibition was in the style or ovary had binucleate pollen.

Citrus

Nagai and Tanikawa (1928) determined several citrus varieites to be self-incompatible. Self incompatibility as a possible cause of seedlessness in *Citrus grandis* (Linn.) Osbeck had long been discussed (Boyle 1914, Reinking and Groff, 1921, Torres, 1932) but only during the last fifteen years have controlled pollination tests been made (Nuriyal 1952, Aala 1953, Soost 1964). Lararelle and Miedzyzyrzecki (1936) determined that unfruitfulness in 'Clementine' (*C. reticulata* Balnco) was caused by self-incompatibility. Self-incompatibility was demonstrated in 'Minneola' tangelo (*C. paradisi* Macf. x *C. reticulata*) by Mustard *et al.,* 1956 and in 'Orlando' tangelo (*C. paradisi* X *C. reticulata*) by Krezdorn and Robinson, 1958, Soost (1965) reported 'Sukega' orangelo (*C. paradisi* X *C. sinsensis* (Linn.)) Osbeck to be self-incompatible.

The presence of self-incompatibility in several species or interspecific hybirds suggests that incompatibility is determined by a basic gene system of incompatibility alleles as in many other plant genera. In citrus the incompatibility is controlled by a series of S alleles determining gametophytic nature of incompatibility.

Carlos, J. T. & Krezdorn (1968), reported that when Orlando tangelos were self-pollinated at anthesis, the pollen tube growth was slower than when cross-pollinated with Parson Brown Sweet Orange. This indicated that slow pollen tube growth in the style was a major cause of self incompatibility during these investigations. The equal rate of growth of pollen tubes of both selfs and crosses from pollinations made at preanthesis stages, however, suggest the inhibitors present incompatible pistils anthesis at not present in the prenathesis stages.

Self-incompatibility was reported in 'Clementine' (Citrus reticulata Blanco) by Soost (1956) in 'Orlando (*C. paradisi*) Macf. *X. C. reticulate*) by Krezdorn and Robinson (1958) and in 'Minneola' (*C. paradisi* X *C. reticulate*) by Mustard *et al.* (1956).

The U. S. Department of Agriculture developed and named the varieties 'Robinson' 'Lee', Osceoal' and 'Nova' which are hybrids of Clementine × Orlando (Reece *et al.*, 1959, 1964) and 'Page', a hybrid of Minneola X Clementine hybrids might require cross-pollination to obtain good crops of fruit. Reece and Register (1961) reported that Robinson requires cross-pollination.

The results of the studies of controlled pollination of Robinson, Lee, Nova and Page made by C.J. Hearn *et al.* (1969) show that each is self-incompatible ; only Page shows a significant set of parthenocarpic fruit.

Lee and Orlando appeared to be the most effective pollen sources for Robinson, but Temple was nearly as good. The most effective pollens for Lee were Orlando and Page.

Orlando pollen gave the best results on Nova, followed closely by Temple, Lee and Page pollens.

In 1966, Page pollinated by Lee produced the largest fruit and Page by Orlando and Temple were next in size. In 1967 Page open pollinated pollinated by Lee or Orlando produced fruit of the same size. Fruits set from Temple pollen were smaller than those from Orlando pollen. Regardless of pollen source, there was a positive linear relationship between fruit size and number of seeds per fruit. On the basis of large fruit size with fewer seeds, after hand pollination, Lee would be considered the best pollinizer for Page.

Among Page fruits containing equivalent numbers of seeds, fruits set from Lee pollen were larger than those set from other pollen varieties. This is apparently the result of metaxenia, and is one of the first cases of this kind reported. Nova and Robinson were poor pollinizers for Page—perhaps because of cross-incompatibility.

Torres suggested self incompatibility as the cause of the failure of a pummelo variety to set fruit by controlled self-pollination. Nauriyal (1962) reported better fruit set with cross-pollination than with self or open pollination in pummelos and indicated self incompatibility as the reason. The result of the studies made by Soost (1964) indicate that 10 of the pummelo accessions tested are likely to be self incompatible. The accumulating evidence indicates that seedlessness in *C. grandis* may generally be expected only when cross pollination is prevented.

In cross pollination trials of Robinson (1960) the pollen of simple orange induced the highest percentage of fruit set in tangelo. Hensz (1964) reported that both Orlando and Duncan pollen germinated on Orlando stigmas and both produced pollen tubes which grew to the base of the styles and penetrated the upper ovary. Here, however, the Orlando pollen tube growth was inhibited, whereas Duncan pollen tubes penetrated the embryo sets and affected fertilization. A growth substance named Promoter II having an Rf value similar to that of IIA, was isolated from extracts of styles and ovaries. The production of promoter II in the Orlando pistil was stimulated by the presence of pollen tubes. It is suggested that parthenocarpic fruit set in Orlando is controlled by endogenous concentrations of promoter II and that greater fruit set following cross pollination is due to the increased production of promoter II associated with endosperm development. None of the growth substances extracted was considered responsible for self-incompatibility.

Diware (1970) while studying with seedless lemon concluded that the variety is seedless because it is self incompatible. The fruit of this variety sets parthenocarpically.

Mango

Singh (1962) conducted studies on self-incompatibility in Dashehari variety of mango. He reported that self flowers developed fruit only to the pea stage when the fruitlets turned yellow and dropped. They contained small, shrievelled and empty ovules. Open pollinated and cross pollinated flowers produced fruit which ripened normally.

Sharma (1969) reported that all four varieties of mango under study viz. 'Dashehari, Langra, Chausa & Bombay Green' are self unfruitful. Initial fruit set following self pollination is negligible (0.0 to 1.68%) as compared with that after cross pollination (6.40 to 23.4%). From the 15th day after pollination, the selfed fruitlets were invariably the smaller. The majority dropped within about 4 weeks of pollination and none attained even half grown size. An analysis of the causes of this showed that the processes culminating in ovule fertilization were the same as after compatible cross pollination. The differences between self and cross pollination became apparent from the 15th day after pollination when degeneration of the endosperm and the surrounding nucellus was widespread after slefing. Saha & Chonkar (1972) reported that Langra with Gulabkhas and Zardalu & Fazali with Langda gave no initial fruit setting. Landga seems to be cross incompatible with Zardalu & Bulabkhas, when Langda serves the female parent and Fazali has also the character of cross incompatibility with Langda when the same is used as female parent.

Singh *etal.* (1972) undertook studies to find out causes of self incompatibility in Dashehari mango. In their studies the amount of inhibitor was found to be less in cross pollinated fruitlets as compared to self pollinated ones. One of the most important salient features of the finding is that the level of IAA like substances having Rf values from 3 to 4 was always higher in cross pollinated fruitlets as compared to self pollinated ones. With advance age of fruitlets as a result of cross pollination, their amount continued to increase. It showed that endogenous growth regulating substances do play in important role in governing the physiology of developing fruits in mango.

Grape

Studies carried out by Deshmukh (1924) to find out the causes of poor yield in the Pandhari Sahebi grape showed that the variety failed to set fruit properly unless adequate pollination was available from some other variety. Cheema (1928) observed that the variety Pandhari Sahebi is partially incompatible and hence the yields are poor. However, with adequate pollination from the other varieties the variety fruited well

Derman (1954) published papers dealing with hybridization of *Vitis vinifera* into *V. rotindifolia* and the fertility of diploid and allotetraploid hybrids. Using the diploid F_1 hybrids, which exhibited almost complete ovule and pollensterility, he produced allotetraploids by colchicine treatment and described them as " fully fertile hybrids." In reciprocal crosses of auto tetraploid clones of *V. vinifera* and *V. rotundifolia*, he failed to obtain set even when *V. vinifera* was used as a female parent (1964). He concluded that the cross incompatibility reaction between the 2 species is strengthened at the tetraploid level. The cause of the difficulties in obtaining the hybrids at the diploid level and the subsequent sterility he attributed to the different chromosome numbers of the two species.

In regard to crossing behaviour of the tetraploids whenever tetrapoid *V. rotundifolia* is used as female, pollination with *V. vinifera* fails to produce berry set. The reciporcal cross is successful as reported in many experiments by Jelenkovie & Vola (1969). Their results are not consistent with Dermen (1964) who reported complete failure of setting in all crosses at the tetrapliod level. The allotetraploids revaled almost identical crossing pattern as the diploid hybrids reported in earlier papers.

Unilateral failure in crosses is common in species that posses gametophytic or sporphytic incompatibility systems (Martin, 1964). However, this cannot be reconciled to either of these two systems.

The two species i.e. *V. vinifera* and *V. rotundifolia* are distantly related and taxonomists have classified them into different subgenera : *V. vinifera* with other grape species (2n = 38) with the subgenus euritis and *V. rotundifolia* with *V. munsonaiana* (2n = 40) in the subgenus muscadinia. The breeding work had indicated that the two sps. hybridize successfully only when *V. vinifera varieties* are used as female parents and *V. rotundifolia* varieties as male parents.

In regard to crossability of P1 hybrid, the P1 hybrids are reciprocally crossable with *V. vinifera* vars. but can only serve as female parents with *V. rotundifolia*. Evidence from breeding tests indicates that incompatibility between *V. rotundifolia.* × *V. vinifera* is not due to cytoplasmic inheritance, but is caused by nuclear factors.

Narasimhan and Mukharjee (1970) made observations on the set of fruit and seed and the occurrence of empty seeds in diploids tetraploids and diploid tetraploid crosses in the vars. Bharat Early, Black Prince, Pearl of Csaba, Maleling Angevine and Nadeline Royal Late abortion of ovules resulting in empty seeds in the tetraploid was related to the shortening of period II of berry growth, to the early and greater accumulation of total soluble solids, to the earlier onset of period III and to the higher rate of ovary growth. The consequent lack of adjustment between the rates of growth of the endosperm and the ovary probably led to somatoplastic sterility.

A study was made of the pollen and pollination of cardinal vines by Lepadatu (1966). The pollen was found to have higher degree of viability and germination capacity. The variety, however, appeared to have vary selective properties in the generative stage, and, although ovules were formed, some of them had imperfections and structural variations resulted in the uneven development of the 60 per cent of the berries.

Observations were made on the effect of supplementary pollination of Bharat Early and Pusa seedless vines with pollen from several different vars. by Uppal and Mukherjee (1968). They found that the bunch wt. and number of grape per bunch of Bharat Early were markedly increased by supplementary pollination with Pearl of Csaba and Pasa Seedless pollen. It may be assumed that the vars. under study may be partialy incompatible and hence with the adequate pollen from other varieties must have induced a satisfactory fruit set.

Guava

Seth (1962) reported that the incompatibility in some guava varieties was due to the inhibition of the growth of pollen tube after it had penetrated into the style.

21 guava clones of different origins were crossed and self-pollinated during several flowering cycles by Ito & Nakasone H (1968). They

did not find any apparent incompability system in the diploid varieties tested, except when Indonesian seedless a triploid was used as male parent. Some crosses yielded few mature fruits, but from those fruits harvested hundred of seeds were viable.

Hirano and Nakasone (1969) undertook the studies of pollen germination and compatibility of some psidium species. They found pollen of different species with high chromosome numbers had poor germination percentages. Pollination studies indicated partial self incompatibility in all the species studied. Reciprocal interspecific crosses showed pronounced differences in compatibility.

Nair *et al.* (1963) reported morphological differences in pollen of guava. However, the differences are restricted to the size of grains, there being big and small ones, the frequency of which varies in the different varieties.

Ber

As reported by Teaotia & Chauhan (1963, Banarasi Pewandi, Ber Thronless and Banarasi Karka were found to be self incompatible for practical purposes. In addition the varieties Ber thronless and Banarasi Karaka are reciprocally cross incompatible.

Loquat

On the basis of the studies of self fruitfulness made by Singh & Rajpur (1962), the loquat variates are classified into two groups:

(*a*) Self incompatible Golden Yellow, Improved Golden Yellow, Pale Yellow and Large Agra ;

(*b*) Partially self-incompatible : Large Bound, Fire Ball, Thames Pride, California Advance and Tanaka.

Self incompatibility in loquat was found to be that of gametophytic nature. It was observed in the varieties Improved Golden Yellow, Pale Yellow and Golden Yellow that pollen tubes penetrated the styler canal upto ¼th to ⅓rd of its length and did not go further even after 72 hours of pollination. This suggested that self-incompatibility in loquat is of a genetophytic nature, because in sporaphytic type of self-incompatibility, only germination of pollen grains is inhibited. In this study California Advance variety was found to be best pollinizer for Improved Golden yellow and Pale Yellow varieties.

Apple

Overholser *et al* (1931) reported that there are appreciable plantings of several red coloured bud mutations of standard named commercial varieties. The growers are interested in knowing the pollination status of these red strains with respect to whether they are self-fertile, inter fertile with other commercial varieties. The work conducted upto 1931, demonstrates that Delicious is self-unfruitful. Bud sport varieties and their parents here studied that seem to be satisfactory pollinizers for the Delicious are Blackjon, King John, Red Rome, Jonathan and Rome. Those varieties that appear to be cross-unfruitful with Delicious are Red Stayman, Richard, Shotwell Delicious, Starking and Winesap.

Whitehouse and Anchter (1926) found that the pollen of Golden Delicious gave a set of only 5.7 per cent upon the Delicious when the normal set was 16.7 per cent.

Since the Delicious is self-unfruitful, it is not inconsistent to find that the Richard, a mutation of the Delicious, is inter-unfruitful with the latter as shown by four year data. Morries and Luce (1928) also reported this to be the case.

Overholster *et al.* (1931) reported that Winesap is self-unfruitful. Those varieties and strains which are good or satisfactory pollinizers for the Winesap are : Delicious, Richard, Starking, Golden Delicious, King John and Red Rome. Red Stayman and Stayman appear cross-unfruitful upon Winesap. The Richard was also self-unfruitful, failed to set satisfactorily with pollen from Delicious, Starking and Shotwell Delicious. The data show Starking Delicious to be self-unfruitful and to be inter-unfruitful with Delicious and Shotwell Delicious. Varieties indicated as satisfactory pollinizers for the Starking are Blackjon, Golden Delicious, and White Winter Pearmain.

Mac Daviels (1928) reported that Northern Spy is self-unfruitful under New York conditions, a fact to be suspected from results obtained elsewhere.

Legasse (1928) found that the Chaplain (Nyack Pippin) and Lily of Kent varieties of apples are self-unfruitful in Delaware. Actual brushing of the pollen upon the stigmatic surface did not increase the set of fruit in the case of the Lily of Kent. Of several varieties tested Rome Beauty is recommended for interplanting with the Chaplain (Nyack Pippin) and Delicious or Griwes Golden with the Lily of Kent.

Vanderacek (1964) studied the pollination relationship. The incompatibility was confirmed in the combination Blenheim x Goldparmane, Boskoop x Crocels, Canada Reinetta x Corncels and Canada Reintette x Goldparmane.

Studies on the floral biology of variety Conventiana apple and of Rosa made by Battalne (1964), have shown that they are incompatible and that each is self-unfruitful.

The trials of Strydom (1962) indicated that in case of Granny Smith, Dunns Seedling x Golden Delicious pollen tubes did not grow more than one third of the way down the style.

Schaldlak (1963) reported that various degrees of self-unfruitfulness can occur, depending on variety and climatic conditions. Fertility in some varital combinations showed an influence of the maternal parent. The cross Biesterfelder x Cox is reported as unfruitful. Only general conclusions could be drawn from studies on pollen tube growth in the style.

Schmallak (1966) reported that the longituudinal growth of apple pollen tubes was influenced by the compatibility of the partners. Combination of Zabergau and Goldparmane and Biesterfelder x Cos and Biesterfelder x Cos Pomona are unfruitful.

Observations of Vondracek (1962) on 33 varieties indicated that apples in general have only a slight tendency to set fruit without cross pollination. The best fruit set and satisfactory fruit size without pollination with pollen of suitable variety was obtained in Ontario, Wagener, Ribston and Laxton's Superb. Boxkoop and Metano nearly always fruited but the fruit size was not satisfactory. Triploid varieties were more prone to set fruit without cross pollination than the deploid varieties. Incompatibility may be broken through polyploidy i.e. triploidy, Polypoidy has thus induced self-compatibility.

Williams (1966) reported that the methods of lengthening the effective pollination period of shy cropping varieties are needed to be investigated. These include the acceleration of pollen tube growth rate and the extension of ovule longivity.

Rome Beauty and Galia are partially cross-fruitful. The combination of Cortland pollinated by Early McIntosh is not sufficiently fruitful. Both are seedlings of McIntosh. Several examples of such cross-incompatibility are : Delicious and all its strains such as Starking, Richard and Shotwell Delicious. Duchess, Dannil's Red Duchess and Van Buren Red Duchess. Cox's Orange Pippin and Laxton's Superb. Jonathan, Jonard and Blackjon. McIntosh lackmack as well as other strains of McIntosh. Northern Spy and Red sp. Ribston Pippin and Cox Pomona.

Pear

Waite (1895) studied the pollination requirements of pears and recorded the first case of incompatibility in fruit trees. He found that plants of the same (clonal) variety were cross-incompatible. De Vries (1906, cited in East, 1929) demonstrated that the individuals in the progeny obtained by crossing two self-incompatible plants consisted of groups—crosses within each group being incompatible and crosses between groups fertile. Crane (1925) showed that the varieties of *Prunus avium* could be divided into a few intra-sterile, inter-feltile groups.

Many workers have reported the existence of self and cross-incompatibility in pear. Even the same variety may behave differently in different localities as Walte (1894) reported Kieffer as self-fruitful in California while Fletcher (1909-10) reported it practically self-unfruitful in Virginia.

Mukherjee and Rana (1966) reported that all the varieties under study started flowering simultaneously within a week's time and showed complete overlapping of full bloom period.

All the pear varieties did not set fruit when selfed. Hand pollination gave 24 per cent fruit set in Leconte. Artificial crosspollination gave higher percentage of fruit than the natural pollination in all the pear varieties. Under Delhi conditions Le Conte was found to be self-fruitful as well as cross compatible with Kieffer and Smith, but Kieffer and Smith were found to be self unfruitful as well as cross-incompatible with each other.

The fruit set under natural conditions was the highest in Le Conte (18. 6 per cent) and the lowest in Smith (5.9 per cent).

Luce and Morris (1928) conducted pollination experiments with Beuree d'Anjou. Evidence as to the variable partial self-fertility of the Beurre d' Anjou was obtained by Tufts and Philp (1923) who reported that when selfed under interior valley conditions in California the per cent set was as follows: (a) 1919, 6.1 (b) 1920, 0.6 (c) 1922, 20.4. In the Sierra Nevada food hills, however, the Beuree d' Anjou was complete self-unfruitful during two seasons. The self unfruitfulness of the Beuree d' Anjou is appreciably influenced by tree vigour. Each of the other varieties tested proved to be satisfactory pollinators for the Beuree d' Anjou. The Bartlett, Flemish, Beauty, Beuree Bose, Winter Nellis and Easter Beuree each gave a set of over 45 per cent when used as pollinizers.

All varieties of European pear and those of hybrid origin such as Keiffer have been found to be self-unfruitful. Pear varieties also fall into two groups and those varieties which are triploid (51 chromosomes) possess non viable pollen and are consequently ineffective in cross-pollination. The varieties Bartlett' Seckel were found to be partially to completely cross and self incompatible in the studies made by Olez (1966). The degree of cross incompatibility in reciprocal crosses and with environmental conditions of which temperature is factor. The incompatibilie reaction occurred after the pollen tubes were half-way down the style and increased in intensity through the basal portion of the style.

Peach

With a few exceptions all important peach varieties have been found to be self-fruitful. The variety J. H. Hale, however has been shown to be self-unfruitful and practically no fruit are borne unless pollen from another variety is available. Likewise June Drop appears to be self-unfruitful for all practical purposes, and the Late Crawford is usually benefitted by cross pollination. Fortunately the pollen of most varieties whose time of blooming synchronise with these varieties cause good fruitset. Varieties such as Elberta and Brackett will no doubt make better pollinizers than others under field conditions because their blooming periods overlap quite well with J. H. Hale. The June Elberta and Late Crawford are also successfully crossed by practically all commercial varieties.

Plum

Self-unfruitfulness is so common in the plum that it generally is accepted as the prevailing condition, though some noteworthy exceptions occur, as in several varieties in *Prunus domestics*. In Minnesota and other states of the upper Mississippi Valley the plums grown are largely hybrids of the oriental species *P. salicina* and *P. simonii* combined in simple and complex hybrids with native species. In addition, there is a considerable number of cultivated varieties representing the native species in the pure form. Both native and hybrid varieities are uniformly self unfruitful even when grown under as nearly optimum conditions as may be provided in a green house.

In trials over 5 seasons carried out by Thiele (1964) no fruit set was obtained from self or inter pollination of the cultivators Golden King, Kelsey & Meriposa. However, all 3 cultivars gave a high per cent of fruit set which combined as male or female parents with a compatible cultivar such as Gaviota & Methley. Histological studies showed that in both compatible and incompatible combinations the pollen grains germinated within 24 hours but in the latter the pollen tubes were confined to the upper half of the styles even 120 hour after the pollination. In incompatible combinations the pollen tube tips appeared to be normal.

The Skopelon clone of Prune d'Agen is completely self incompatible as reported by Raptopoulous (1967), although the original trees imported from France were self compatible. Another clone of Prune de' Agen sets only 15 per cent. of fruit with self pollination, thus needing a pollinator variety to ensure profitable yields. The variety Asvestochorion is completely self incompatible. The variety Imperial prune is also self incompatible, but is a good pollinate for the above types and produces fruit of a good quality as that of Skopelon, Coe's

Golden Drop and Asvestochorion are cross incompatible. High yields resulted from pollination of Skopelon, Prune d'Agen and Asvestochoriaon by Victoria, Harris, Monarch, Golden Gage and Czar.

The trials conducted by Yoshide (1963) showed that hybrids obtained from the same parents were generally incompatible with each other and were often incompatible with one or both parents. Hybrids from different parents were mainly compatible with each other. The hybrid seedlings offered were often tricotyledonous especially when Orei was the female parent.

Fruit set is generally poor in most of the Japanese plums for want of pollination though Beauty, Climex Mathyley and Santa Rosa are partly self unfruitful. These varieties will also be benefitted in fruit set if provision of cross-pollination is made. The degree of self-fruitness of these varieties apparently varies grom place to place depending upon local environmental conditions.

European plums and prunes:

Usually self-fruitful	—	French, Stanely, Sugar.
Partly self-fruitful		Italian prune, Green Gage.
Self-unfruitful	—	Jefferson, President, Tragedy, Dennis-ton's Superb, Warwickshire Dropper.

The partly self-unfruitful varieties should generally not be planted without provision for cross-pollination.

Almond

Since the edible part of the almond is the seed, fertilization of the egg is essential. All commercial varieties of almond are self-unfruitful and required cross pollination by insects to produce a crop. That there is a distinct pollination problem in almond was recognized as early as 1885, when Hatch (1886) pointed out that California Languedoc trees planted near seedlings always produced heavier crops than when planted in solid block. To obtain a maximum crop in the almond, therefore, essentially 100 per cent of the flowers shoud be cross-pollinated.

Criggs (1953) and Gagnaro (1954) reported that all the varieties under cultivation in California and Algeria required cross-pollination for proper fruit set. Tuft (1919) observed self-incompatibility in all the 17 varieties studied at Davis. However, he held that self-incompatibility was not a constant factor in a variety, for it may be barren in one locality and self-fruitful in another and the the degree of adaptation of a variety to soil and climate had much to do with its ability to fruit abundently with its own pollen.

Nauriyal & Rana (1965) reported that all the varieties except Drake gave the evidence of self-incompatibility. Almond varieties, being self-incompatible should not be planted in solid block without provision for pollinizer variety. The variety Non-pareil proved to be the best pollinizer for all the other three varieties tested.

Main Variety	*Polinizer Varieties*
Thin Shelled ..	Out of the three varieties tested only Non-pareil proved to be the best pollinizer. Ne-Plus-Ultra and Drake gave rather poor set.
Drake	Non-Pareil, Ne-Plus-Ultra & Thin Shelled proved very good pollinizers.
Non-Pareil ..	Thin Shelled & Drake gave good results. Ne-Ulus-Ultra yielded poor fruit set.
Ne-Plus-Ultra ..	None of three varieties provided to be very satisfactory pollinizers, the fruit set less than 11 per cent.

Cherry

All sweet cherries of any commercial importance have satisfactory pollen germinability. But almost all the cherry varieties tested in the United States, England, Germany, Sweden and elsewhere have been found to be self-unfruitful. Practically no fruits whatsoever were obtained from self-pollination.

Not all varietal combinations are fruitful, since there is considerable cross-incompatbility between varieties. More than a dozen groups are now known which contain varieties recprocally incompatible, and the number is being augmented with further research. The varieties within any one group are all closely related, being either seedlings or bud mutations of some parent variety. Such groups are as follows :—

1. Napoleon, Bing, Lambert, Emperor Francia, and Ohio Beauty.
2. Early Purple and Rockport.
3. Advance and Rockport.
4. Windsor and Abundance.
5. Elton, Wood and Stark's Gold.

6. Black Tartarian, Knight's Early Black, Early Rivers, Bedford Prolific, and Black Eagle.
7. Centennial and Napoleon.

Group No. 1 contains several varieites commercially prominent in this country. As has been previously indicated incompatibility within this and the other groups is belived to be governed by a series of multiple allelomorphic genes. The varieties within a group contain the same genes in the style as in the pollen, a fact which results in failure of the pollen tubes to reach the ovary and effect fertilization.

Various strains have been found in Napoleon, Bing, Lambert, Black Republican, and Black Tartarian which do not respond equally to pollination tests. In all likelihood this is due to the fact that seedlings of these varieties which now exist are probably so similar in appearance to the original varieites as to make it difficult to distinguish them from their parents. It has thus become necessory in using Black Tartarian, for instance, as a pollinizer to select trees of strains known to be capable of fertilizing the chosen variety.

Way (1968) identified the specific sterility genes and incomptibility groups of 20 sweet cherry cultivars and seedlings that have not previously been reported. Identification was made of a new incompatibility group, group XIII, S_2 S_4 Compatibility studies showed that venus and vic cannot have the parents that they are reported to have. Incompatibility was used as evidence to show that Buttners Rote Knorpelkirsche and Emperos Francis could be the same clone.

Results of pollination trials in Netherland were compiled to detect groups of inter incompatible cherry varieties by De Vries (1968). In sweet cherry there appeared to be at least 6 groups of inter incompatible varieties, in sour cherry only one such group was found. Moreover, two groups of intercompatible sour and hybrid cherry (*P. arium x P. cerasus*).

Bugbricie (1968) found that the Pandy variety Kereska 1 & 2 and Chese Morello were self unfruitful, the Pandy types were compatible with Chese Morello, Majska, Umbra, Dychouse, Domaca, Rich Morency and Montmorency and the Pandy types were inter compatible.

Rasberry

Zych (1964) reported that red x black & purple x black combinations were completed incompatible. Red x purple, x purple x purple and purple selfed produced fruit usually of normal appearance, but with some irregularity indicating some incompatibility. Pollen tubes in the incompatible crosses did not progress beyond the upper third of the style and exhibited a marked thickening of the wall at the tip.

Zych (1965) made controlled pollination in a green house involving 10 varieties of black rasberry (*Rubus occidentalis*). Three varieties of the red rasberry (*R. idacus* L) and four varieties of the purple rasberry (*R. neglectus*) red x black and purple x black combinations were completely incompatible. Red x purple, purple x purple and purple selfed produced fruit usually of normal appearance, but with some irregularity, indicating some incompatibility. All other combinations were fully compatible. Pollen tubes in the incompatible crosses did not progress beyond the upper third of the style and exhibited a marked thickening of the wall at the tip. Normal pollen tube growth and fertilization occurred in the compatible combinations.

Pineapple

Majumdar *et al.* (1963) reported that the variety Smooth Cayenne was highly self incompatible. Callose fluorescence technique was applied in studies of pollen growth in pineapple styless. The assessment of self and cross incompatibilities by this laboratory technique correlated well with field pollination data.

Brewbaker (1957) pointed out that most species in which incompatible tubes reach the ovary have hollow style ; he suggested that intimate contact between pollen tubes and stylar tissue is necessary for inhibition to occur. The recent findings that incompatible tubes are not inhibited by the hollow styles of *Ananas* (Pineapple) (Brewbaker & Gorrez, 1967), lend support to this view.

Quince

Schanderl (1966) while studying floral biology of different quince varieties reported four out of seven varieties to be self-incompatible and two self-fertile.

Incompatibility and Plant Breeding

Duvick (1966) and Lundqvist (1969) have reported that the occurrence and use of incompatibility, whether genotophytic or sporophytic may be of advantage or disadvantage in the breeding of plants. This mechanism provides a way to produce hybrids between two lines without emasculation. At the same time, it also creates problems in producing inbred lines required for producing the hybrid. The relative advantages or disadvantages of incompatibility are determined by economic value of the part of the crop (whether seed or vegetative portion) and the method of reproduction of the crop (whether sexual or asexual).

Self-incompatibility as an aid

Self-incompatibility is useful :

(i) In the case of seedless varieties where the fruits must not contain seed as in the pineapple.

(ii) In the production of triploids by planting alternate rows of self-incompatible diploids and tetraploids—this is possible where self-incompatibility does not breakdown at the tetraploid level.

(iii) In the production of hybrid varieties where S-homozygotes can occur as in the *Brassica* crops. The inbred lines can be produced in a number of ways. Odland and Noll (1950) proposed developing inbred lines of cabbage through (1) bud pollination, (2) selection of pseudocompatible lines, and (3) asexual reproduction of self-incompatible clones. The inbred lines could be used to produce single-cross and subsequently double-cross hybrid seed. The inbreds lines by using these methods have been produced in cabbage, marrow-stem kale, and Brussels sprouts and are being used to produce commercial F1 hybrid seed (North, 1969) ; Odland, 1965 ; Johnson, 1964). The single cross hybrid is used for commercial production, where the crop is not the seed as in Chinese cabbage. The use of double-cross has to be made, where the crop is for seed.

Self-incompetibility aids but is not essential

When the crop is not raised for seeds, self-incompatibility can be of advantage. In ornamental and leafy and root crops, self-incompatibility, by preventing seed production, will prolong the blooming period of the ornamentals and the vegetative phase in vegetables.

Self-incompatibility as a bottleneck

In grain crops, self-incompatibility is a hindrance because of :

(i) variation in seed set,

(ii) problems of preserving genetic purity of improved varieties, and

(iii) difficulties of producing inbreds and maintaining them.

In the vegetatively propagated plants such as apple self-incompatibility is a hindrance in planting single variations. Two or more cross-compatible varieties have to be grown to induce fruitfulness. It is, therefore desirable to introduce self-fertility alleles into such crops in order to regularize the pollination process and to permit the planting of orchards to single varieties.

Incompatibility is thus of great importance in the breeding of crops, particularly in species in which vegetative plant parts are consumed.

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